

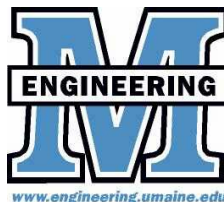


**A STUDY FOR  
BORALEX ENERGY, INC.**

**FATE OF DIOXIN AND ARSENIC FROM THE  
COMBUSTION OF CONSTRUCTION AND DEMOLITION  
DEBRIS AND TREATED WOOD**

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## EXECUTIVE SUMMARY

This study was carried out in response to recent concerns regarding dioxin/furan (PCDD/F) and arsenic concentrations in potential fuel sources for biomass boilers in Maine and the resulting concentrations in the combustion byproducts. The sources of PCDD/F and arsenic are poorly understood. It is thought that chromated copper arsenate (CCA) treated wood is a significant contributor to arsenic concentrations, but its importance relative to other sources has not been quantified. Pentachlorophenol treated wood contains high levels of PCDD/F, however this material is thought to be absent from construction demolition debris (CDD) used as a fuel source for biomass boilers. Thus, the source of PCDD/F is unclear. This lack of information has hindered the State of Maine's ability to develop regulations to minimize the presence of arsenic and PCDD/F in the fuel sources for biomass boilers. The objective of this study was to begin to fill in these information gaps.

This study was carried out in three phases. In Phase I the composition of CDD fuel from five municipal sources and three commercial sources as well as one clean wood source was characterized in terms of the physical composition of the samples. The PCDD/F, arsenic, copper, and total/soluble chlorine content of the CCA pressure treated, burnable, painted, plastics, and minus #4 fractions was determined. The chemical composition of creosote and pentachlorophenol treated wood was also examined. In Phase II trial burns were conducted at the Boralex Stratton and Boralex Livermore Falls facilities using three fuel blends that were targeted to have specific concentrations of arsenic and PCDD/F. The chemical composition of the fuel and combustion by-products was measured. In Phase III, the data was assimilated and this report was prepared.

The average physical compositions of CDD from commercial and municipal suppliers are very similar as shown below:

Supplier	Phase I - Composition						Ash Content of Minus #4
	Plastics	Painted	CCA Treated	Burnable	Non-Burnable	Minus #4	
	(%)	(%)	(%)	(%)	(%)	(%)	(%)
<b>Average for three commercial samples</b>	<b>0.9</b>	<b>6.1</b>	<b>1.0</b>	<b>67.4</b>	<b>1.0</b>	<b>23.6</b>	<b>21.2</b>
<b>Average for five municipal samples</b>	<b>0.2</b>	<b>6.8</b>	<b>1.2</b>	<b>68.4</b>	<b>3.4</b>	<b>20.0</b>	<b>22.9</b>
<b>Average for five duplicate municipal samples</b>	<b>0.3</b>	<b>8.7</b>	<b>2.0</b>	<b>64.8</b>	<b>1.2</b>	<b>23.1</b>	<b>25.5</b>

On the average the CCA fraction ranged from 1.0 to 2.0%. For individual samples the CCA fraction ranged from 0.1 to 5.4%. Moreover, the CCA fraction from duplicate

municipal samples differed by a factor of two in some cases. This shows that the CCA content of small samples can be variable.

The arsenic content of the fractions from the commercial (C1-C3), municipal (M1-M5) and duplicate municipal samples (DM1-DM5) are shown below:

Parameter	Units	Fraction	Sample Number		
			C1-C3	M1-M5	DM1-DM5
As	mg/kg	PAINTED	30	778	122
		TREATED	2357	2010	2409
		BURNABLE	43	134	33
		MINUS #4	133	33	25
		PLASTICS	2.2	6.1	7.7
		Total Sample	88	182	88

As expected the arsenic concentration of the CCA treated fraction is very high relative to the other fractions. The arsenic content of the painted, burnable and minus #4 fractions varies between 30 and 778 mg/kg. For some fractions there are significant differences between the municipal and duplicated municipal samples again suggesting that the arsenic content in small samples can be highly variable. The contribution of the CCA fraction to the total arsenic present in the samples ranged from 14.0% to 56.3% with the balance of the arsenic coming from the burnable, painted, and minus #4 fractions. These results suggest that fractions other than the CCA wood contributes a significant portion of the total arsenic. Consideration should be given to the possibility that there is a source of arsenic other than CCA wood or that arsenic from CCA wood is transferred to other fractions during the demolition, grinding, sorting, and shipping processes.

The PCDD/F TEQ of the Phase I CDD samples based on Table 405.1 and USEPA Method 8290, are shown below:

Parameter	Units	Fraction	Sample Number		
			C1-C3	M1-M5	DM1-DM5
Reporting TEQ	pg/g	PAINTED	210.7	10.1	219.4
		TREATED	8.9	2.1	1.7
		BURNABLE	45.9	20.5	41.1
		MINUS #4	2549.2	316.9	101.7
		Total Sample	657.9	81.0	70.1

With the exception of the treated wood fraction for some samples, the concentration was above 4.0 pg/g TEQ referenced under 1.H Prohibition of Chapter 418. For the commercial (C1-C3) and municipal (M1-M5) samples, the minus #4 fractions had the highest reporting TEQ. For the commercial sample the minus #4 fraction contributed 93.2% of the reporting TEQ in the total sample, while this fraction accounted for 81.2% of the reporting TEQ of the municipal sample. For the municipal duplicate the minus #4, burnable, and painted fractions contributed comparable amounts of TEQ to the total sample. The source of the PCDD/F in the minus #4 fraction could not be determined.

For Phase II, trial burns were conducted at Boralex Stratton in December, 2003 and at Livermore Falls in May/June, 2004. The target PCDD/F and arsenic concentrations for each run are shown below:

<b>Run No.</b>	<b>Description</b>	<b>Blend</b>	<b>Target Reporting PCDD/F</b>	<b>Target Arsenic</b>
<b>1</b>	Control	Clean Wood Only	< 4 pg/g – TEQ	< 0.1 mg/kg
<b>2</b>	Low Level	CDD, Clean Wood & Penta-treated wood	16 pg/g – TEQ	6 mg/kg
<b>3</b>	Moderate Level	CDD, Clean Wood & Penta-treated wood	95 pg/g – TEQ	30 mg/kg

For run no. 2, it was estimated that a blend of 10% CDD and 90% clean wood would meet the target arsenic concentration. For run no. 3, a blend of 50% CDD and 50% clean wood was estimated. For both run nos. 2 and 3, pentachlorophenol wood was added to increase the PCDD/F concentration to the target values. The actual arsenic concentration for run no. 1 for both trial burns was greater than the target, where as, it was less than or equal to the target for run nos. 2 and 3. The actual PCDD/F concentrations were both above and below the target values.

There was a general trend that as the arsenic input increases, the arsenic output in the combustion by-products increases. For the Stratton fly ash and stack gas, the trend was relatively uniform. However, for the Stratton bottom ash, the arsenic output was a little lower for the low run as compared to the control run. For each of the Livermore Falls combustion by-products, there was a significant increase in arsenic output between the control and low runs. Moreover, the data showed that the arsenic concentration in the fly ash from the first half of the run was approximately double that of the second half of the run. The Fly Ash A and B samples were composites made by alternately depositing scoops of fly ash into the A and B containers, they were essentially taken over the same time period. Thus, there is no ready explanation for the difference between the arsenic concentrations in the Fly Ash A and B samples. The arsenic concentration in the stack gas for the moderate run at Stratton, and the control and low runs at Livermore Falls may have been affected by one of the precipitator fields being off for all, or a portion of, the measuring period.

The highest arsenic concentration in the stack gas for the Stratton trial burn was 0.0282 mg/dscm for the moderate run and for the Livermore Falls trial burn it was 0.120 mg/dscm for the low run. Modeling performed by MDEP (see Appendix D) showed that “the worst case ambient air impact results from the Livermore Falls facility were only 30% of the MAAG (Maximum Ambient Air Guideline) value for arsenic” and “in the case of the Stratton facility, the worst case impact levels were 3.5% of the MAAG value for arsenic.”

For Stratton, 73.6% to 88.4% of the arsenic in the combustion by-products was contained in the fly ash. For Livermore Falls the fly ash contained 74.9% to 78.1% of the arsenic. This percentage appears to be independent of the level of arsenic input in the

fuel. The stack gas for the Stratton trial burn contained a lower percentage of the arsenic than the Livermore Falls trial burn (0.13% to 0.87% for Stratton compared to 1.72% to 4.08% for Livermore Falls).

Based on reporting TEQ, the PCDD/F output rate varied from 65% below to 9% above the input rate, with the exception of the control run for Stratton where the output rate was 372% greater than the input rate. The reason for the latter result could not be determined. Thus, for five out of the six runs, the PCDD/F output, based on reporting TEQ, ranged from below to roughly equivalent to the PCDD/F input.

There were general trends that as the PCDD/F input increases, the PCDD/F in the combustion by-products increases, however, the trends are nonlinear. The highest reporting TEQ in the stack gas for Stratton occurred in the moderate run (0.162 ng/dscm), whereas the highest value for Livermore Falls occurred in the low run (0.104 ng/dscm). Modeling performed by MDEP (see Appendix D) showed that “the worst case ambient air impact results from the Livermore Falls facility were only ... 0.47% of the MAAG (Maximum Ambient Air Guideline) value for dioxin” and “in the case of the Stratton facility, the worst case impact levels were ... 0.24% of the MAAG value for dioxin.”

For Stratton 88.7% to 97.6% of the reporting TEQ was contained in the fly ash. For Livermore Falls the fly ash contained 95.5% to 98.1% of the reporting TEQ. The percent of the PCDD/F contained in the bottom ash was small being less than 0.32% for five out of the six runs. For the stack gas, the percent reporting TEQ ranged between 1.8% and 11.0%. At Stratton the highest percent was observed for the moderate run where as the lowest percent was observed for this run for the Livermore Falls trial burn. This suggests that the percent of the PCDD/F output in the stack gas is controlled by factors that are in addition to the PCDD/F input alone.

Levels of total chlorine in each of the runs was high relative to the PCDD/F concentrations. Moreover, the total chlorine levels decreased slightly as the percent PCDD/F in the fuel blend increased. This suggests that availability of chlorine was not a controlling factor in the amount of PCDD/F in the combustion by-products.

The copper concentration in the fly and bottom ashes increased as the copper in the fuel increased. Given that the PCDD/F reporting TEQ input and output was roughly the same for several runs, it appears that the presence of increased copper levels does not promote an increase in PCDD/F reporting TEQ.

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## 1. INTRODUCTION

Recent concerns have arisen regarding dioxin/furan (PCDD/F) and arsenic (As) concentrations in potential fuel sources for biomass boilers operated by Boralex Stratton, Inc., and Boralex Livermore Falls, Inc and the resulting concentrations in the combustion byproducts. Samples taken by the Maine Department of Environmental Protection (MDEP) between October 29 and November 5, 2002 were found to have PCDD/F concentrations above the 4.0 pg/g (4.0 ppt) toxic equivalency (TEQ) referenced under 1.H Prohibition of Chapter 418. In addition, arsenic levels in construction and demolition debris (CDD) fuel samples were above the 5.375 mg/kg (5.375 ppm) screening standard found in Appendix A of CMR Chapter 418.

The possible sources of PCDD/F and arsenic are poorly understood. Pentachlorophenol (PCP) treated wood is known to have elevated levels of PCDD/F, yet the CDD fuel sources are thought to be free of this material. It is possible that PCDD/F may be introduced through another component of CDD fuel, but this has never been quantified. Chromated copper arsenate (CCA) treated wood is a possible source of arsenic. Efforts are made to minimize the presence of CCA treated wood in CDD fuel, however, the relative importance of CCA treated wood compared to other components of CDD fuel is unknown. This lack of information has made it difficult to form rational regulatory policies to minimize the release of PCDD/F and arsenic into the environment.

The primary objective of this study was to “generate defensible information that will enable all stakeholders involved to put the right tools in place to substantially reduce or eliminate the presence of PCDD/Fs and arsenic in the CDD fuels”<sup>1</sup> and data on the PCDD/F and arsenic concentrations in the combustion byproducts. The project study proposal<sup>2</sup> stated that the following strategies would be employed:

- “Identify to the greatest extent practicable the source and/or the processes leading to the formation and concentration of the PCDD/Fs and arsenic.”
- “Quantify concentrations of PCDD/Fs and arsenic in the study fuel so that the fuels under study can be properly blended to meet the proposed target concentrations.”
- “Quantify concentrations of PCDD/Fs and arsenic in the “as combusted” blended fuel, gaseous emissions and produced ashes as a function of the blended fuel composition.”
- Assimilate all collected data and produce a quality, comprehensive report. This report shall be provided to all stakeholders as an aid in establishing acceptable limits for PCDD/Fs and arsenic in CDD fuels.”

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<sup>1</sup> Boralex, “Fate of dioxin and arsenic from the combustion of construction and demolition debris and treated wood,” A supplemental environmental project proposal to Maine DEP prepared by Boralex Athens Energy, Inc. and Boralex Fort Fairfield, Inc., as revised September, 26, 2003.

<sup>2</sup> Boralex, *ibid*.

The study was divided into three phases. In Phase I the composition of CDD fuel from five municipal sources, three commercial sources, and one clean wood source was characterized in terms of the physical composition of the samples and the PCDD/F, arsenic, copper, and total/soluble chlorine of the CCA pressure treated, burnable, painted, plastics, and minus #4 fractions. In Phase II trial burns were conducted at the Boralex Stratton and Boralex Livermore Falls facilities using three fuel blends that were targeted to have specific concentrations of arsenic and PCDD/F. The chemical composition of the fuel and the combustion by-products was measured. In Phase III, the data was assimilated and this report was prepared.

Further details of this study may be found in the project study proposal prepared by Boralex<sup>3</sup>. This includes the characteristics of the combustion and emission control units at the Boralex Stratton and Boralex Livermore Falls facilities, the specific steps and procedures that would be performed as part of this study, and proposals from subcontractors who assisted with the execution of this study.

The results of Phase I and Phase II are presented and discussed in the following sections. This is followed by a summary of the key findings from this study.

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<sup>3</sup> Boralex, *ibid*.

## 2. PHASE I – FUEL ANALYSIS

### 2.1 COMPOSITION OF SAMPLES

A visual analysis of the composition of the three commercial samples, five municipal samples, and one sample of clean wood was performed by the University of Maine. The samples were delivered to the University by Boralex Stratton Energy in aluminum foil-lined cardboard boxes. The volume of each sample was approximately 15 gallons. The samples were analyzed in accordance with the CDW Sample Preparation and CDW Physical Analysis Procedures dated November, 2002, which are included as Appendix E. In accordance with this procedure, quartering was used to obtain a representative samples with a volume of about 4 gallons each for visual analysis. The commercial samples were designated C1 through C3. However, for the municipal samples quartering was initially used to divide the samples into two halves. Then, quartering was continued on each half to produce two 4-gallon samples for each municipal supplier. These were called “municipal” and “duplicate municipal” samples. These were designated M1 through M5 and DM1 through DM5. In total, 14 visual analyses were performed.

The samples were separated into the categories shown below.

- Plastics (including, but not limited to: plastic laminates and synthetic carpets)
- Painted wood (painted non-CCA treated wood)
- CCA treated wood
- Burnable (including, but not limited to: non-painted, non-CCA wood; plywood; oriented strand board; particle board; cardboard; and paper)
- Non-burnable (examples include nails, stones, and wire)
- Minus #4 (material passing a #4 sieve, which has a 0.187-in., 4.75-mm square opening size; minus #4 material is too small to be visually classified and likely includes material in all the categories listed above)

The samples were separated into the various categories based on visual observation. Therefore, the percent by weight in each category gives only a general representation of the types of materials in the samples. In addition, the ash content of the minus #4 material was determined in accordance with ASTM D1102-84. Results are expressed as a percent of dry weight of the minus #4 material.

The composition of the samples and ash content of the minus #4 fraction are summarized in Table 1. Complete analytical results are given in Appendix A. In addition, the amount of CDD delivered from each supplier for the Phase II-Stratton Trial Burn is shown in Table 1 along with the percent of the total commercial CDD and municipal CDD delivered. These percentages were used to compute a weighted average of the composition of the commercial, municipal, and duplicate municipal samples. The weighted averages are shown in Table 1 and in Figure 1. There is some difference between the composition of the individual municipal and municipal duplicate samples, however, the average compositions show reasonable agreement. This indicates that the visual separation procedure can result in a good level of repeatability. Overall, the compositions of the commercial and municipal CDD are similar.

Table 1. Composition of Phase I Clean Wood and CDD samples.

Supplier		Phase I - Composition						Ash Content of Minus #4	Phase II Stratton	
		Plastics	Painted	CCA Treated	Burnable	Non-Burnable	Minus #4		Amount Delivered	Percent of Total Delivered
		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(tons)	(%)
<b>Clean wood</b>		0.0	0.0	0.0	59.9	0.0	40.1	15.8	---	---
<b>Commercial</b>	<b>C1</b>	0.5	7.1	1.3	68.9	0.7	21.6	19.5	423.15	33.8
	<b>C2</b>	1.6	9.9	0.9	69.6	1.9	16.1	20.5	370.16	29.5
	<b>C3</b>	0.6	2.1	0.9	64.2	0.7	31.5	23.2	459.84	36.7
	<b>Weighted Average</b>	<b>0.9</b>	<b>6.1</b>	<b>1.0</b>	<b>67.4</b>	<b>1.0</b>	<b>23.6</b>	<b>21.2</b>		
<b>Municipal</b>	<b>M1</b>	0.1	7.2	0.8	71.3	4.8	15.7	23.1	192.03	32.7
	<b>M2</b>	0.4	6.9	2.2	74.9	3.4	12.1	7.7	131.43	22.4
	<b>M3</b>	0.1	7.5	0.7	72.7	2.4	16.6	16.2	92.83	15.8
	<b>M4</b>	0.1	5.1	0.3	48.1	3.1	43.4	62.6	93.91	16.0
	<b>M5</b>	0.2	6.5	2.3	69.9	1.4	19.7	8.3	77.35	13.2
	<b>Weighted Average</b>	<b>0.2</b>	<b>6.8</b>	<b>1.2</b>	<b>68.4</b>	<b>3.4</b>	<b>20.0</b>	<b>22.9</b>		
<b>Duplicate Municipal</b>	<b>DM1</b>	0.1	6.4	0.2	67.6	1.0	24.7	28.6	Same as Municipal	
	<b>DM2</b>	0.1	13.5	5.4	65.7	0.2	15.0	7.0		
	<b>DM3</b>	1.1	9.1	0.8	67.2	2.5	19.3	26.1		
	<b>DM4</b>	0.2	4.6	0.1	55.3	2.4	37.4	59.4		
	<b>DM5</b>	0.4	10.5	4.4	64.8	0.1	19.8	6.9		
	<b>Weighted Average</b>	<b>0.3</b>	<b>8.7</b>	<b>2.0</b>	<b>64.8</b>	<b>1.2</b>	<b>23.1</b>	<b>25.5</b>		



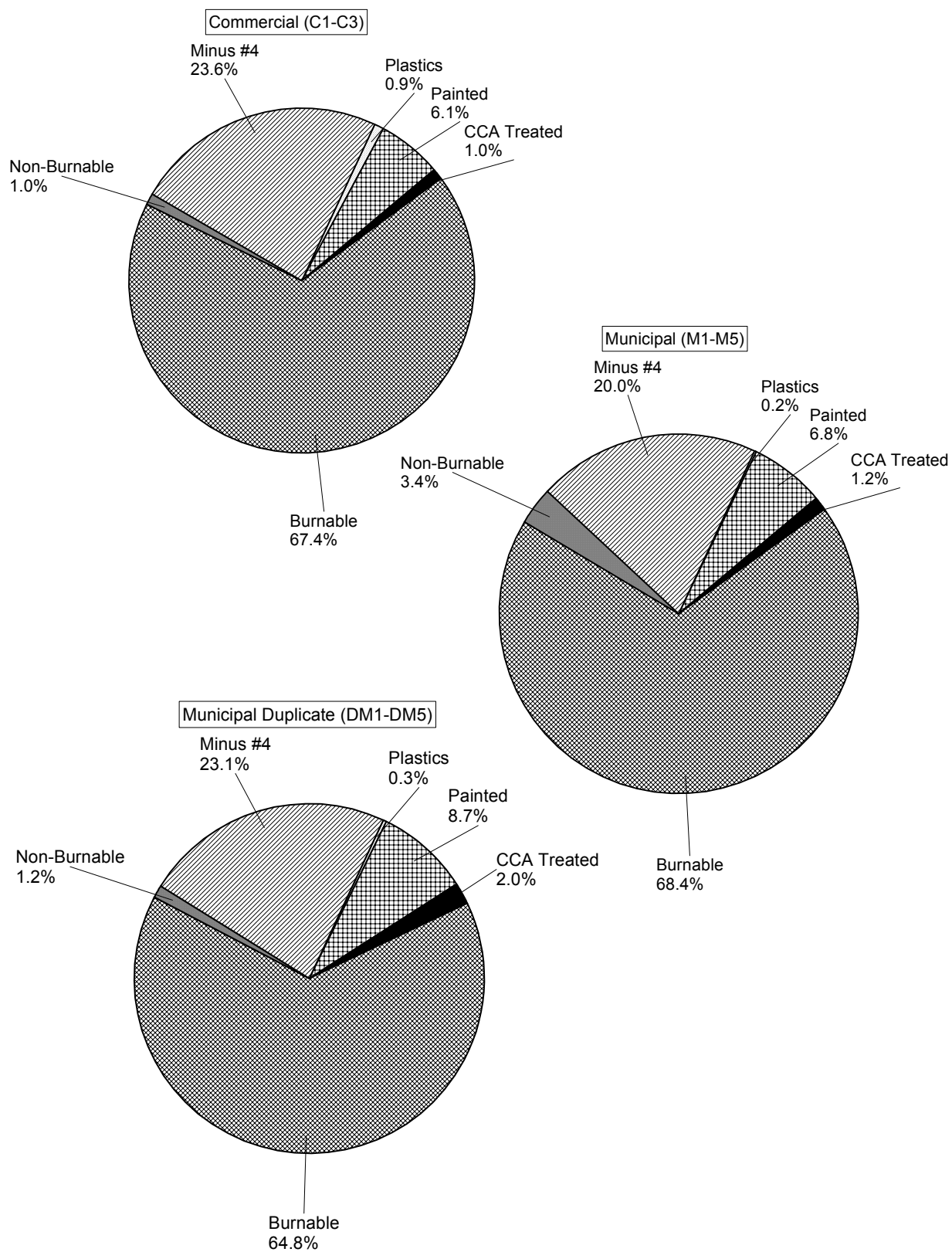


Figure 1. Composition of weighted average of Phase I CDD samples.

## 2.2 CHEMICAL ANALYSIS OF SAMPLES

The possible sources of arsenic (As), copper (Cu), chloride, and dioxin/furans (PCDD/F) was investigated by analyzing the fractions from the three composite samples as well as samples of clean wood, pentachlorophenol treated wood, creosote treated wood, and CCA treated wood. Composite samples were formed to represent the commercial, municipal, and duplicate municipal suppliers. This was done by combining the fractions from each supplier in proportion to the tonnage of CDD delivered from each supplier for the Phase II-Stratton trial burn as shown previously in Table 1.

The results for the samples of clean wood, pentachlorophenol treated wood, creosote treated wood, and CCA treated wood are shown in Table 2. An analysis for arsenic and PCDD/F was also performed on a master CDD sample that was blended in proportion to the amount of commercial and municipal CDD delivered for the Stratton trial burn. These results are also shown in Table 2.

The analytical results for the fractions of the composite samples are shown in Table 3. In addition, for each parameter the concentration in the total sample was computed as a weighted average based on the proportion (by weight) of each fraction in the composite sample. Extractable chloride and total chlorine tests were not done on the plastics fractions because the sample size was too small. Moreover, the laboratory subcontracted to perform the PCDD/F analyses informed us that it was analytically impractical to perform PCDD/F tests on plastics. The concentration of arsenic, copper, extractable chloride, and PCDD/F is further illustrated graphically in Figures 2 through 5. Further discussion and assessment of the measured concentrations of arsenic, copper, chloride, and PCDD/F are presented in the following subsections.

Table 2. Summary of Phase I analytical results of specific wood sources.

Parameter	Units	Clean Wood	Penta	Creosote	CCA Treated	Master CDD	CDD Blank
<b>Arsenic, total</b>	mg/kg	0.8	0.7	4.1	1635	63	N/A
<b>Copper, total</b>	mg/kg	---	3 (J)	25	---	N/A	N/A
<b>Total solids</b>	%	73.80	74.78	67.49	80.12	91.00	N/A
<b>Extractable Chloride</b>	mg/kg	---	82.8	20.1	---	N/A	N/A
<b>Total Chlorine</b>	%	---	0.92	0.02	---	N/A	N/A
<b>Reporting TEQ</b>	pg/g	1.897	27,662	96.65	0.579	40.36	0.462

J = Analyte was positively identified/Associated value is an estimate below detection limit. Also indicates an estimated result due to an associated QC problem.

N/A = not applicable.

Table 3. Summary of Phase I analytical results of sample fractions.

Parameter	Units	Fraction	Sample Number		
			C1-C3	M1-M5	DM1-DM5
As	mg/kg	PAINTED	30	778	122
		TREATED	2357	2010	2409
		BURNABLE	43	134	33
		MINUS #4	133	33	25
		PLASTICS	2.2	6.1	7.7
		Total Sample	88	182	88
Cu	mg/kg	PAINTED	21	276	77
		TREATED	1710	1500	1660
		BURNABLE	3 (J)	35	39
		MINUS #4	37	131	27
		PLASTICS	41	5	2 (J)
		Total Sample	30	90	73
% Solids	%	PAINTED	92.34	92.55	92.49
		TREATED	93.33	93.28	93.4
		BURNABLE	91.67	93.18	92.33
		MINUS #4	78.08	85.95	84.86
		PLASTICS	98.07	97.78	97.22
		Total Sample	88.46	91.64	90.62
Extractable Chloride	mg/kg	PAINTED	21.8	75.5	62.5
		TREATED	19.2	189	23.1
		BURNABLE	34.6	56.5	40.1
		MINUS #4	64.8	105	155
		Total Sample	40.91	69.57	68.63
Total Chlorine	%	PAINTED	0.08	0.12	0.1
		TREATED	0.02	0.06	0.03
		BURNABLE	0.08	0.08	0.08
		MINUS #4	0.09	0.1	0.11
		Total Sample	0.08	0.09	0.09
Reporting TEQ	pg/g	PAINTED	210.7	10.1	219.4
		TREATED	8.9	2.1	1.7
		BURNABLE	45.9	20.5	41.1
		MINUS #4	2549.2	316.9	101.7
		Total Sample	657.9	81.0	70.1

Note: Values reported for the total sample were determined as a weighted average based on the proportion (by weight) of each fraction in the total sample.

J = Analyte was positively identified/Associated value is an estimate below detection limit. Also indicates an estimated result due to an associated QC problem.

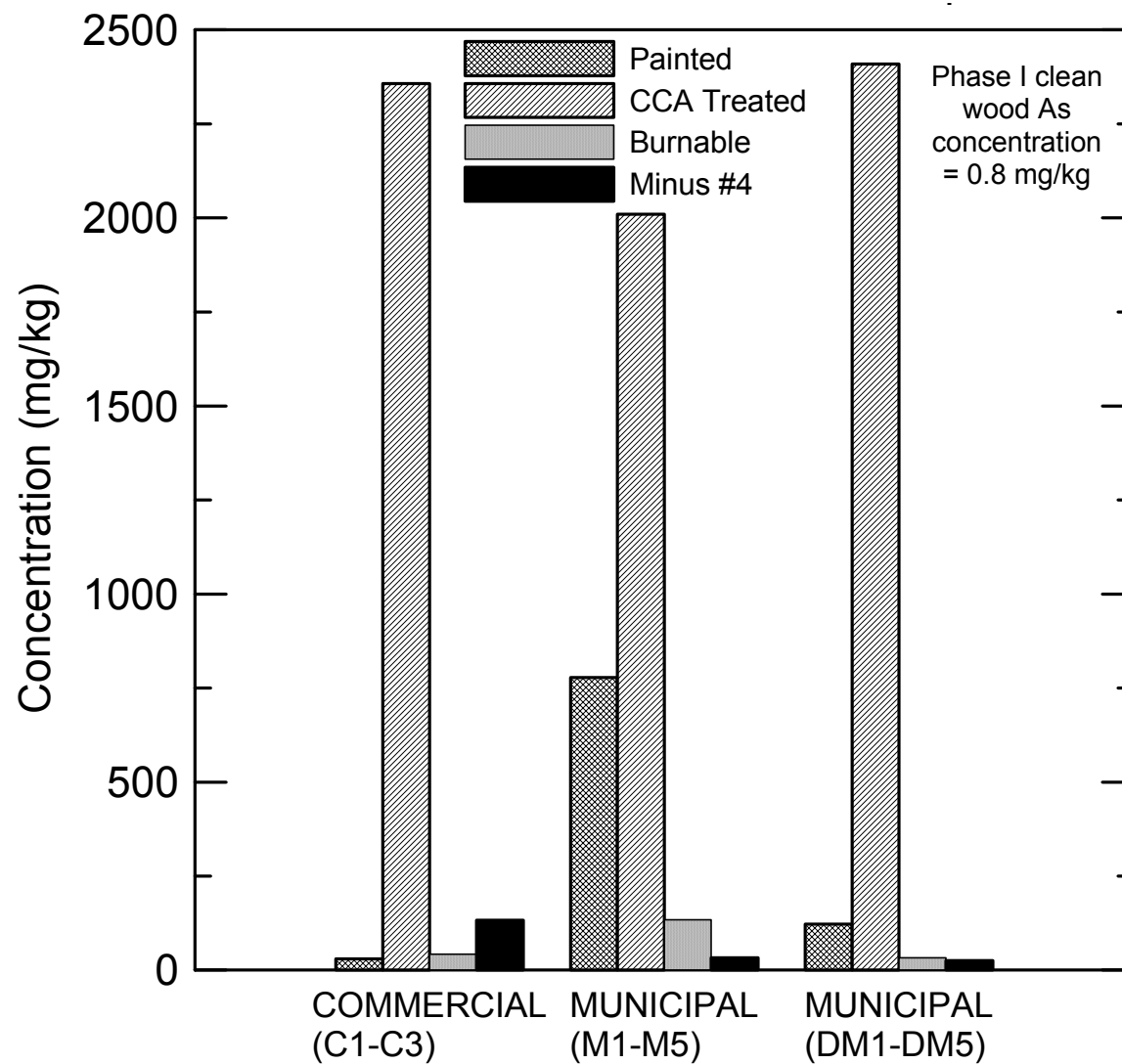


Figure 2. Arsenic (As) concentration in Phase I sample fractions.

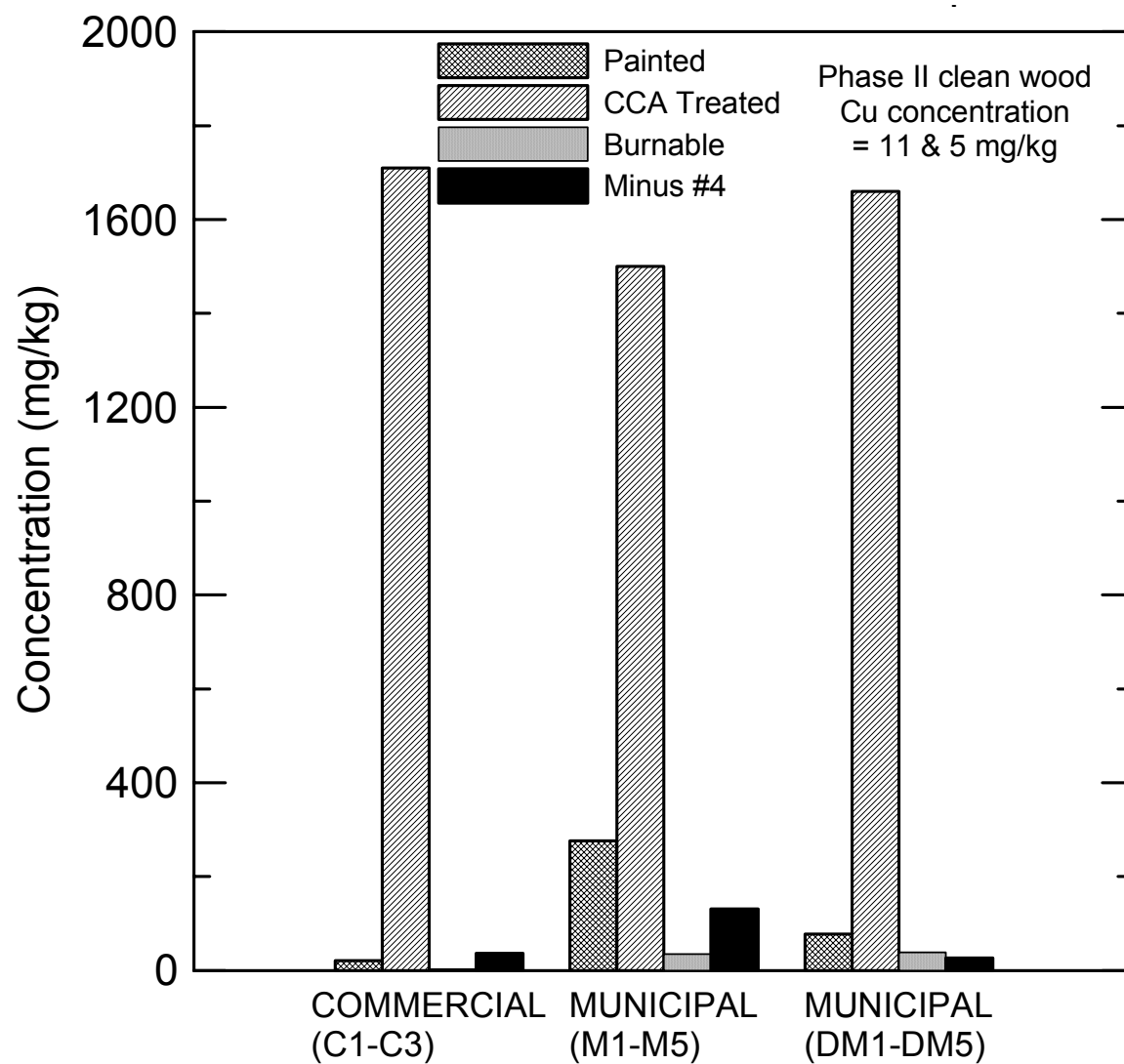


Figure 3. Copper (Cu) concentration in Phase I sample fractions.

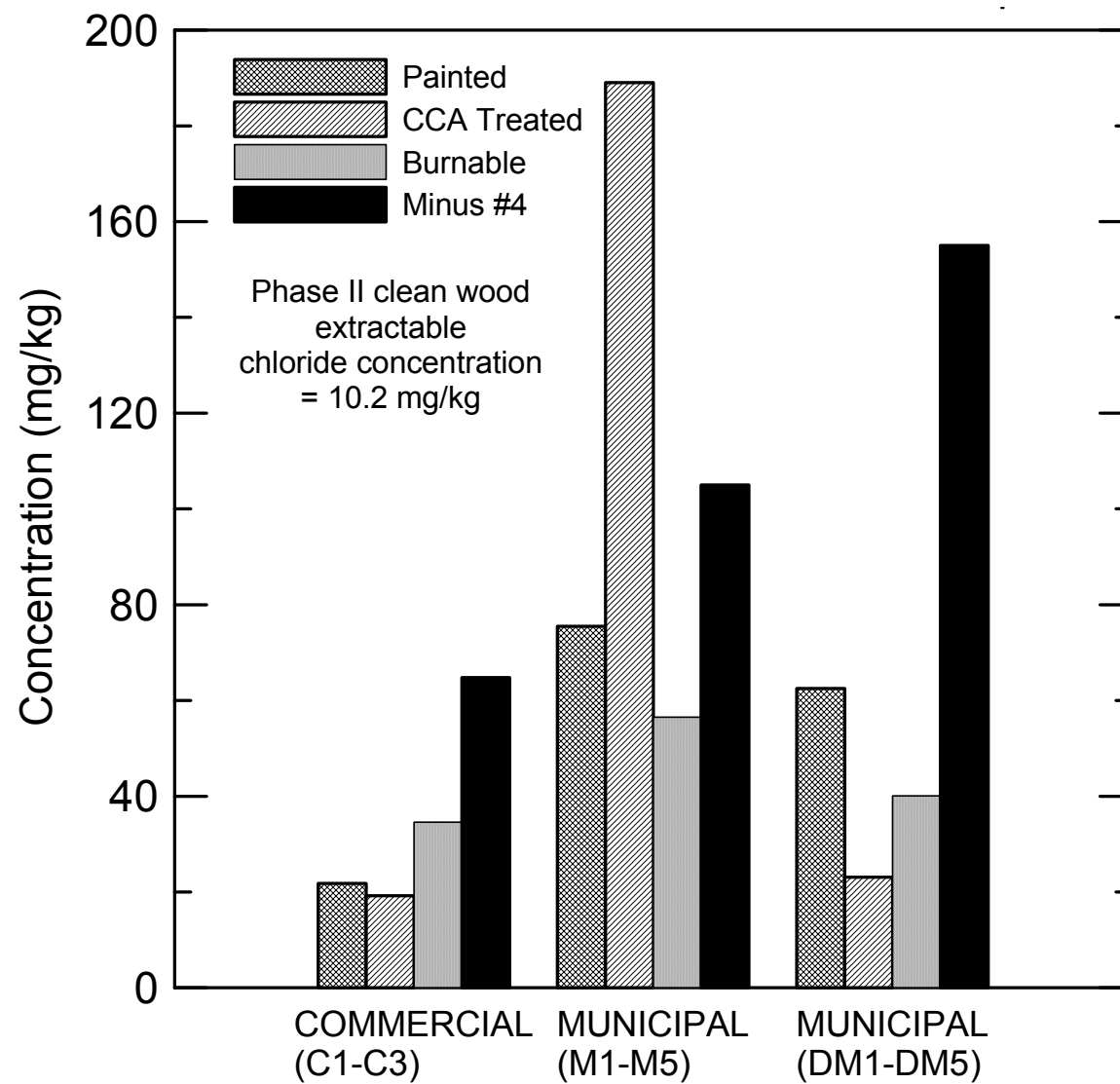


Figure 4. Extractable chloride concentration in Phase I sample fractions.

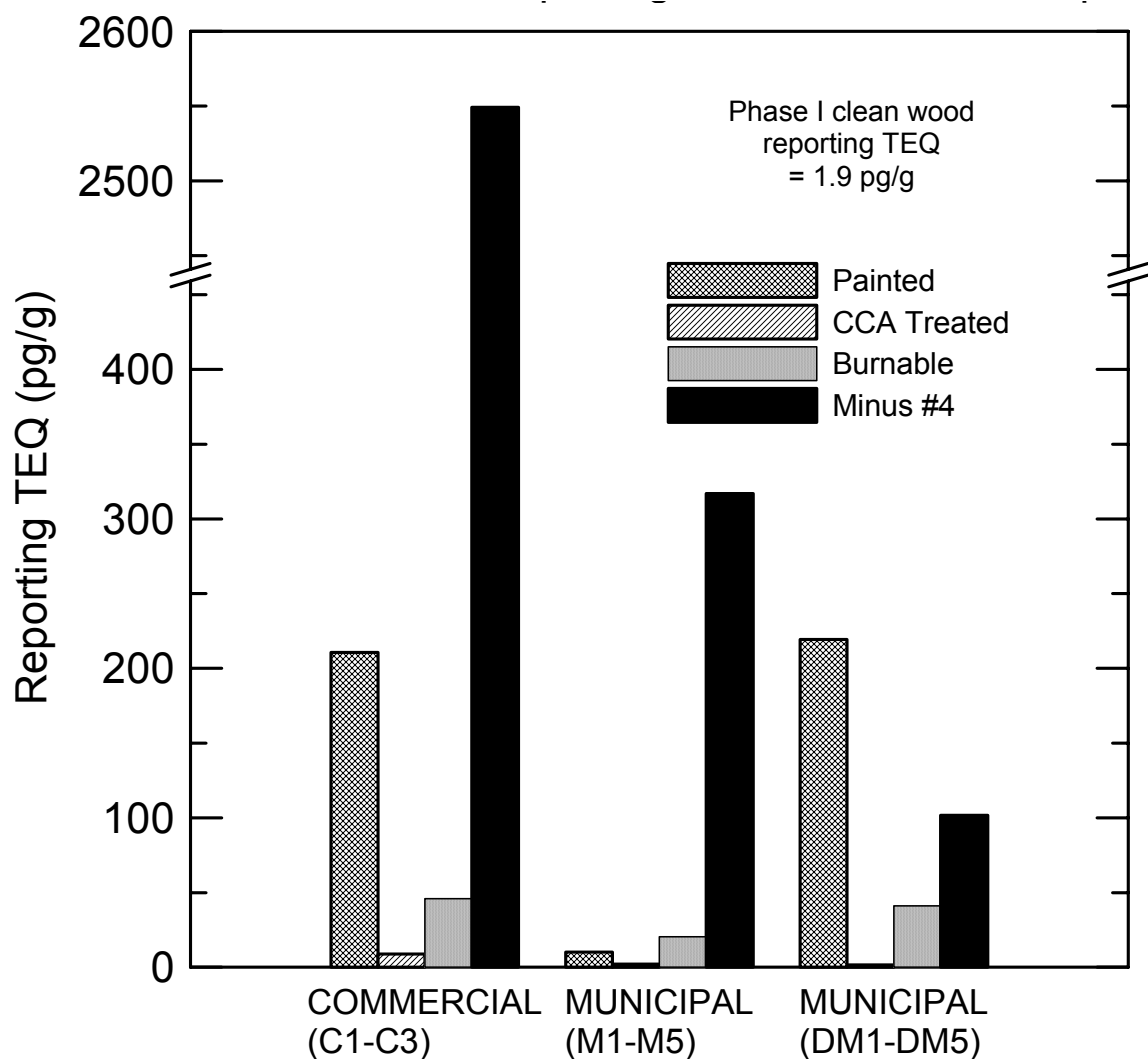


Figure 5. PCDD/F reporting TEQ in Phase I sample fractions.

### 2.2.1 Arsenic

The arsenic concentrations in the CCA treated wood fractions (Table 3 and Figure 2) and for the individual sample of CCA wood (Table 2) is three orders of magnitude greater than that of clean wood. The painted wood, burnable wood, and minus #4 fractions also have elevated levels of arsenic with concentrations one to two orders of magnitude greater than for clean wood. However, the pentrachlorophenol and creosote treated wood samples had arsenic concentrations (Table 3) that were the same order of magnitude as clean wood indicating that they would not be expected to be a significant source of arsenic.

The contribution of each fraction to the arsenic in the total sample was investigated further using the measured arsenic concentration in conjunction with the proportion, by weight, of each fraction in the total sample. The arsenic contribution of the plastics fractions were less than 0.02% for each sample and was neglected in the analysis. The non-burnable fraction was not analyzed for arsenic and was also neglected. The results are presented as the percent that each fraction contributes to the arsenic in the total sample as shown in Figure 6. The contribution of the CCA fraction to the total arsenic concentration ranged from 14.0% to 56.3% with the balance of the arsenic coming from the burnable, painted, and minus #4 fractions. These results suggest that fractions other than the CCA wood fraction contributes a significant portion of the total arsenic.

The possibility that the arsenic in the burnable and painted fractions could be an artifact of an imperfect sorting process that allowed some CCA treated wood to remain in these fractions was considered. The arsenic concentration in the burnable wood fractions ranged from 33 to 134 mg/kg. To produce these concentrations by CCA contamination, the fractions would require that approximately 2% to 8% by weight of CCA treated wood remained in the burnable wood fraction after sorting. Similarly, the painted fractions would need to contain 2% to 48% CCA treated wood to obtain the arsenic concentrations given in Table 3. While it is possible that some CCA treated wood remained in burnable and painted wood fractions, it is unlikely that such a large amount of CCA wood remained undetected. Consideration should be given to the possibility that there is a source of arsenic other than CCA wood or that arsenic from CCA wood is transferred to other fractions during demolition, grinding, sorting, and shipping.

The minus #4 fraction would be expected to contain small particles of CCA treated wood that result from grinding the material. To obtain the arsenic concentrations given in Table 3 would require 8% CCA for Sample C1-C3, 2.0% for M1-M5, and 1.4% for DM1-DM5. For comparison the CCA fraction was 1.0% by weight for C1-C3, 1.2% for M1-M5, and 2.0% for DM1-DM5. For sample C1-C3, the results suggest that there is a source of arsenic in addition to CCA treated wood that is responsible for raising the concentrations above those expected for clean wood.

### **2.2.2 Copper**

The copper (Cu) concentrations in the CCA treated wood fractions (Table 3 and Figure 3) are two orders of magnitude greater than that of clean wood, which was taken to be 8 mg/kg based on Phase II testing. The painted wood, burnable wood, and minus #4 fractions also have higher levels of copper with concentrations 2 to 35 times greater than for clean wood. For the CCA treated wood fractions the ratio of the arsenic concentration divided by the copper concentrations ranged between 1.34 and 1.45 indicating a strong correlation between the concentration of these elements as would be expected for CCA treated wood. The sample of pentachlorophenol treated wood has a copper concentration less than that of clean wood whereas the concentration was about three times greater for creosote treated wood (Table 2).



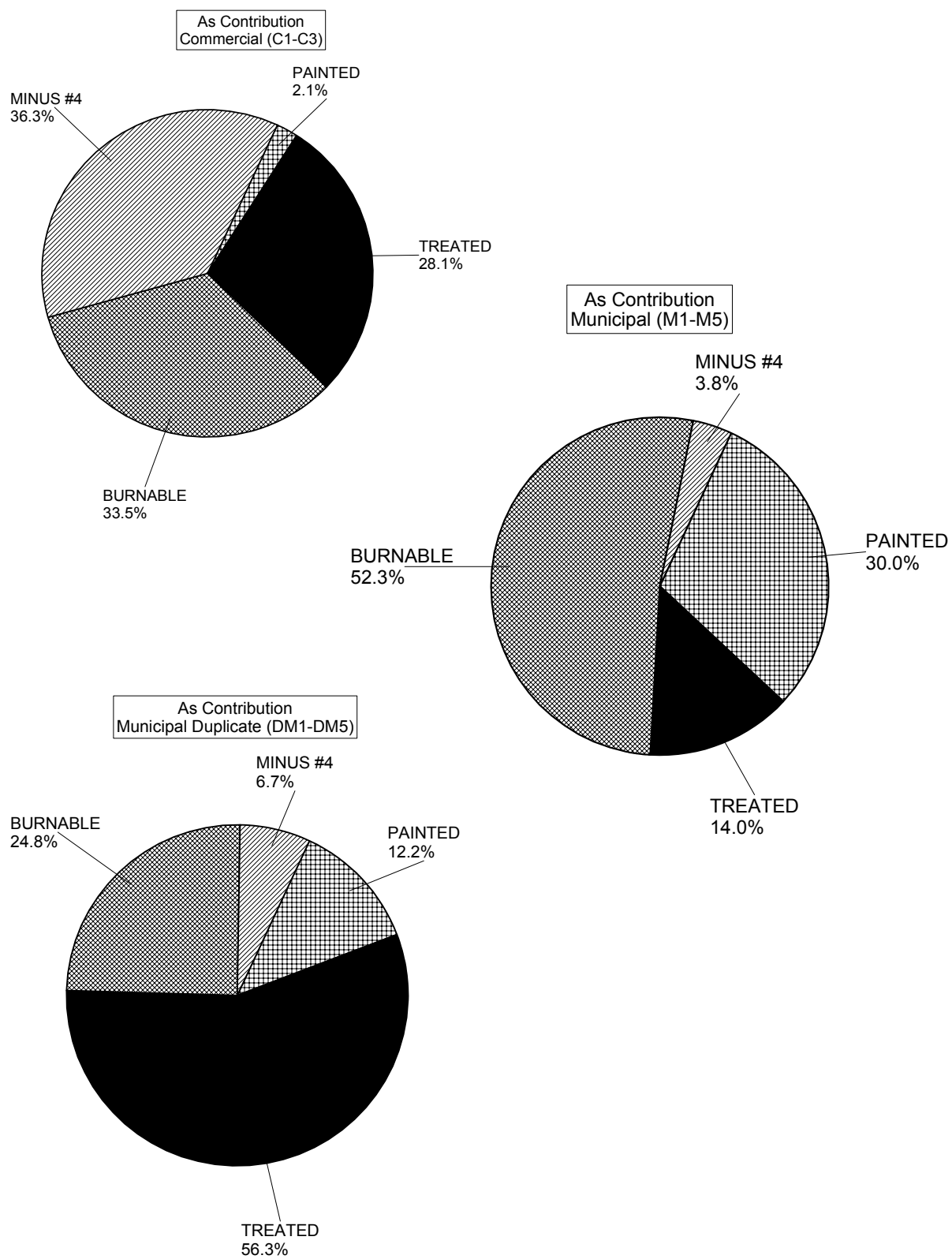


Figure 6. Relative contribution of each fraction to the total arsenic concentration.

The contribution of each fraction to the copper in the total sample was investigated further using the measured Cu concentration in conjunction with the proportion, by weight, of each fraction in the total sample. The copper contribution of the plastics fractions was 1.2% for the commercial sample but was less than 0.01% for municipal and municipal duplicate samples. Accordingly, the copper contribution of plastics was considered for the commercial sample, but was neglected for the municipal and municipal duplicate samples. The non-burnable fraction was not analyzed for copper and was neglected. The results are presented as the percent that each fraction contributes to the copper in the total sample as shown in Figure 7. The contribution of the CCA treated wood fraction to the total copper concentration ranged from 21.0 to 58.8% with the balance of the copper coming from the burnable, painted, and minus #4 fractions. Plastics also contributed copper for the commercial sample. These results suggest that fractions other than the CCA fraction contributes a significant portion of the copper.

In a similar manner to the discussion in Section 2.2.1, the possibility that the copper in the burnable and painted fractions could be an artifact of an imperfect sorting process was considered. For the burnable fractions of the municipal and duplicate municipal samples about 2% CCA treated wood would need to have remained in the sorted fraction. Similarly, the painted fractions would need to contain 1% to 17% CCA treated wood to obtain the copper concentrations given in Table 3. It is possible that some CCA treated wood was present in the sorted burnable and painted fractions, it is unlikely that CCA contamination could completely explain the presence of copper at levels well above that of clean wood.

The minus #4 fraction would be expected to contain small particles of CCA treated wood that result from grinding the material. To obtain the copper concentrations given in Table 3 would require 1.8% CCA for Sample C1-C3, 7.6% for M1-M5, and 1.1% for DM1-DM5. For comparison the CCA fraction was 1.0% by weight for C1-C3, 1.2% for M1-M5, and 2.0% for DM1-DM5. For two out of the three samples, the results suggest that there is a source of copper in addition to CCA treated wood that is in part responsible for raising the concentrations above those expected for clean wood.

### 2.2.3 Chloride

The extractable chloride concentrations of the fractions are shown in Table 3 and Figure 4. For the commercial and duplicate municipal samples, the minus #4 fraction had the highest total chloride concentration. For the municipal sample the CCA treated wood fraction had the highest extractable chloride concentration. The percent total chlorine in the fractions ranged from 0.02 to 0.12% as shown in Table 2. Chloride results for the plastic fractions are unavailable because there was insufficient sample mass for testing.

The contribution of each fraction to the extractable chloride in the total sample was investigated further using the measured chloride concentration in conjunction with the proportion of each fraction in the total sample. Results are presented as the percent that each fraction contributes to the chloride in the total sample as shown in Figure 8. The

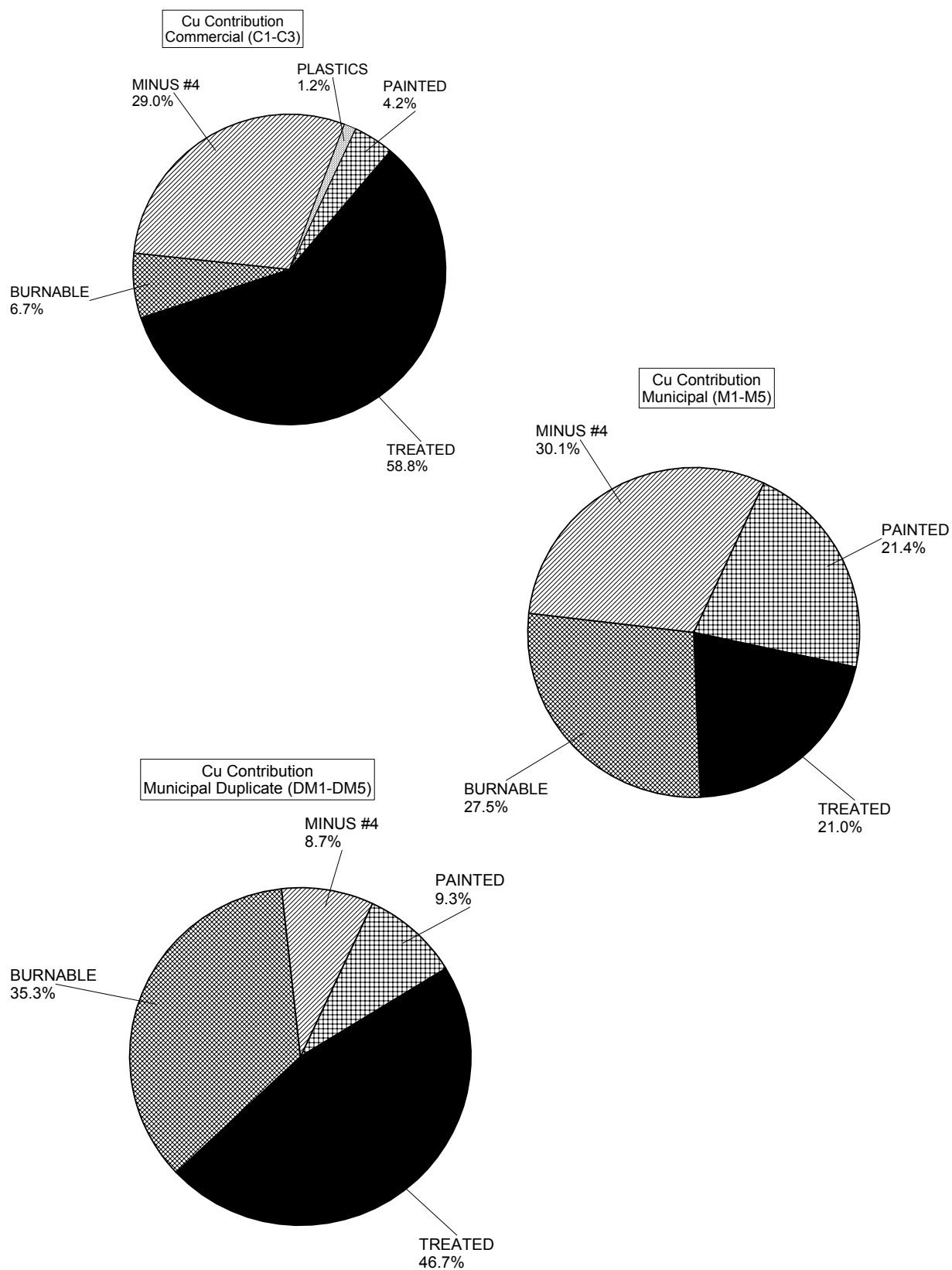


Figure 7. Relative contribution of each fraction to the total copper concentration.

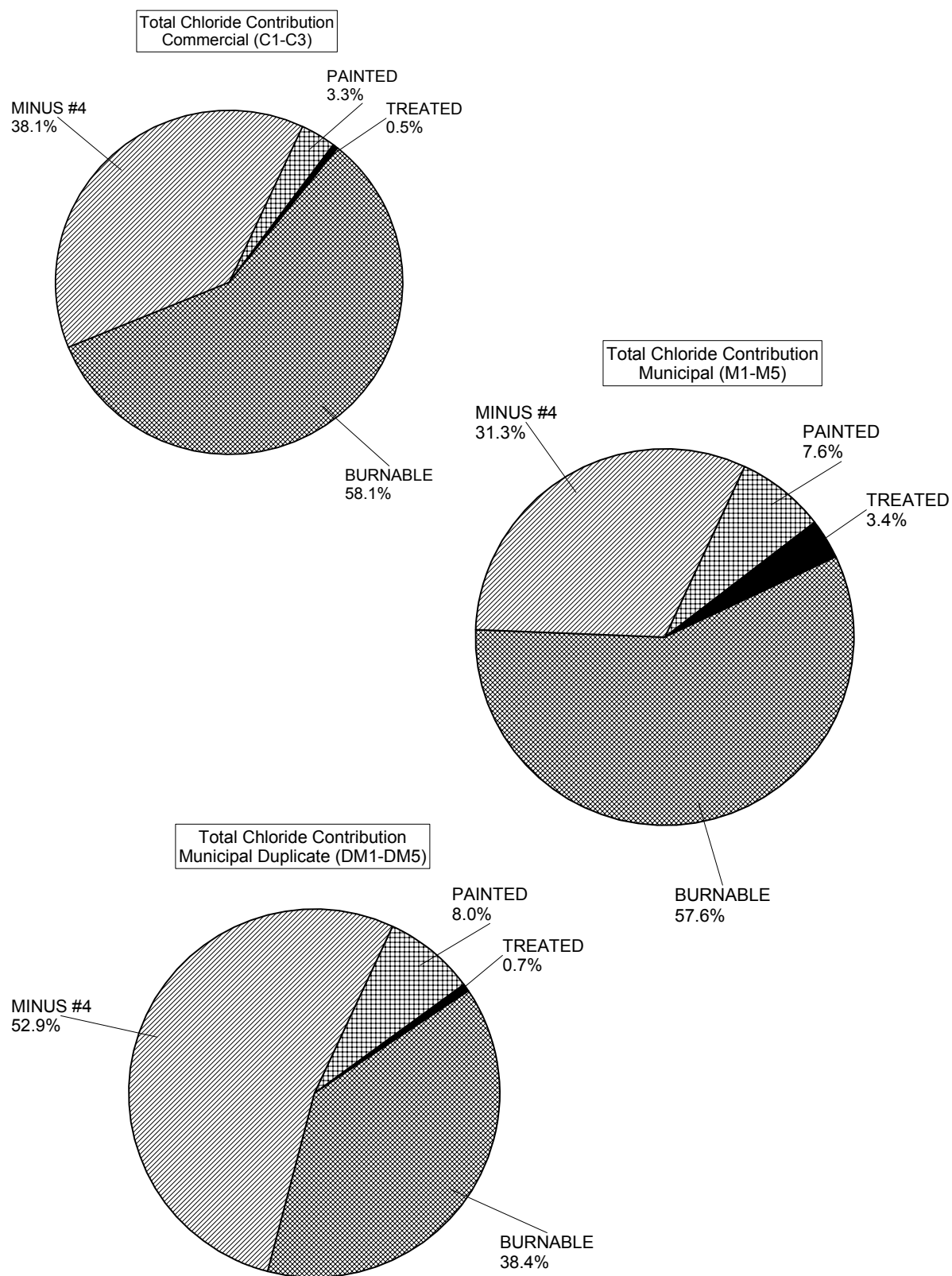


Figure 8. Relative contribution of each fraction to the total chloride concentration.

combination of the painted and treated fractions accounted for between 3.8% and 11% of the chloride in the total sample. Thus, burnable and minus #4 fractions are the source of the vast majority of the chloride in the samples.

#### **2.2.4 Dioxin/Furan**

The PCDD/F results were examined in terms of the reporting TEQ as shown in Table 3 and Figure 5. With the exception of treated wood fraction for some samples, the concentration was above 4.0 pg/g TEQ referenced under 1.H Prohibition of Chapter 418. For the commercial and municipal samples, the minus #4 fraction had the highest reporting TEQ's. Moreover, the TEQ's of minus #4 fraction for the commercial sample were more than an order of magnitude greater than the other fractions. However, for the duplicate municipal sample, the painted fraction had the highest TEQ's. All the fractions had TEQ's greater than that of clean wood (reporting TEQ = 1.9 pg/g). As shown in Table 2, the TEQ's of pentachlorophenol treated wood is four orders of magnitude greater than clean wood. Thus, if it were present in CDD, it could be a significant source of PCDD/F. For creosote treated wood the reporting TEQ is 51 times that of clean wood.

The contribution of each fraction to the TEQ in the total sample was investigated further using the measured TEQ in conjunction with the proportion, by weight, of each fraction in the total sample. The results are presented as the percent that each fraction contributes to the reporting TEQ in the total sample as shown in Figure 9. For the commercial sample the minus #4 fraction contributed 93.2% of the reporting TEQ, while this fraction accounted for 81.2% of the reporting TEQ of the municipal sample. For the municipal duplicate the minus #4, burnable, and painted fractions contributed comparable amounts of TEQ to the total sample. The source of the PCDD/F in the minus #4 fraction could not be determined. For each sample, the contribution of the CCA treated fraction was insignificant.

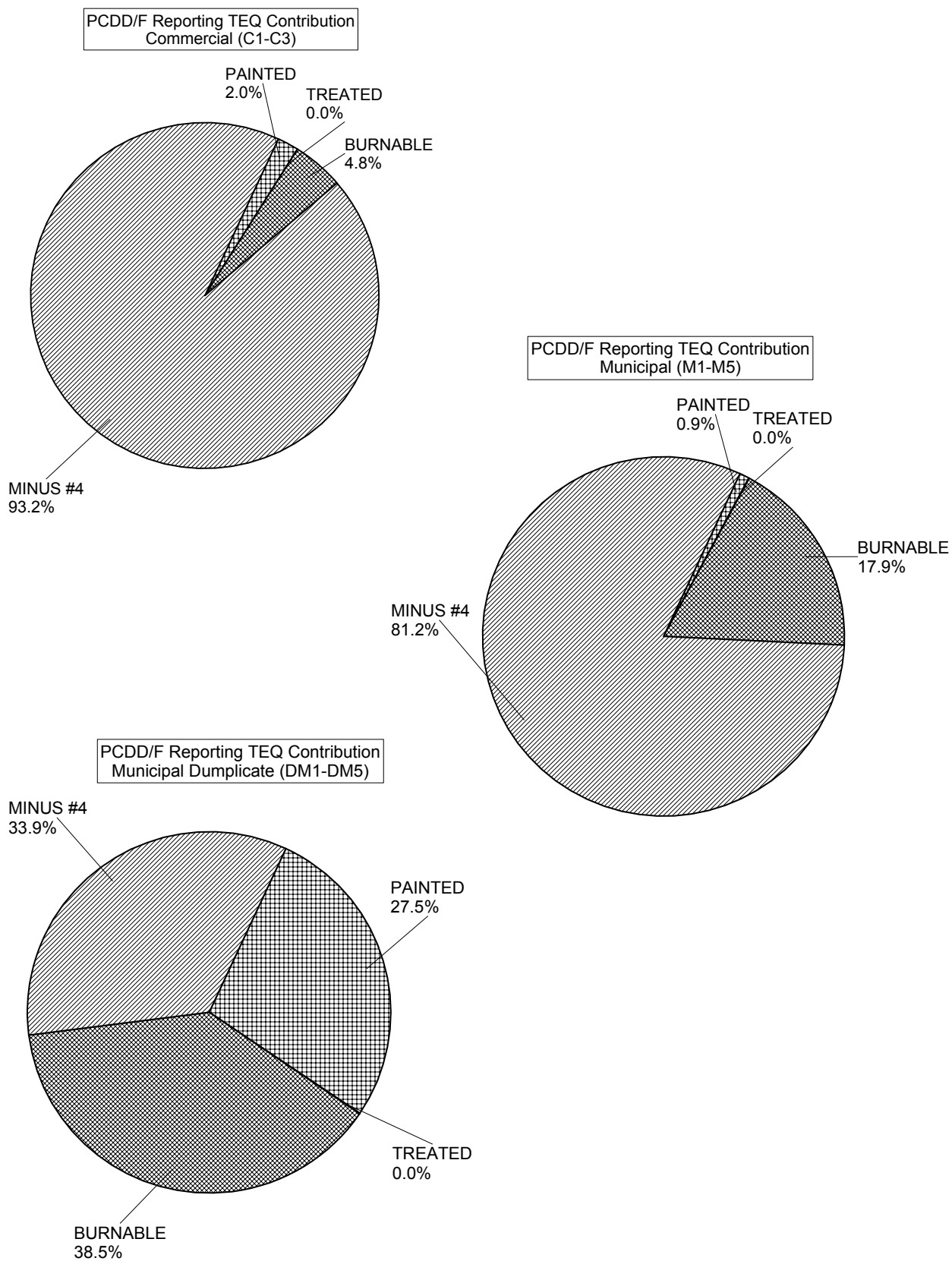


Figure 9. Relative contribution of each fraction to the PCDD/F reporting TEQ.

### 3. PHASE II – BORALEX STRATTON AND BORALEX LIVERMORE FALLS TRIAL BURNS

#### 3.1 INTRODUCTION

The initial step in Phase II was to determine the PCDD/F and arsenic concentrations in potential fuel sources including: clean wood, CDD, CCA treated wood, and pentachlorophenol treated wood. These results were used to proportion the fuel blends for each run to meet the targets given in Table 4. The Stratton trial burn occurred on December 9 through 12, 2003. The Livermore Falls trial burn occurred on May 25, June 16, and June 17, 2004. The as-combusted fuel and the combustion by-products were analyzed for arsenic, copper, and PCDD/F concentrations. Data was subjected to Tier II review. The results are presented in the following sections.

Table 4. Fuel blends and target PCDD/F and arsenic levels.

Run No.	Description	Blend	Target Reporting TEQ for PCDD/F	Target Arsenic
1	Control	Clean Wood Only	< 4 pg/g – TEQ	< 0.1 mg/kg
2	Low Level	CDD, Clean Wood & Penta-treated wood	16 pg/g – TEQ	6 mg/kg
3	Moderate Level	CDD, Clean Wood & Penta-treated wood	95 pg/g – TEQ	30 mg/kg

#### 3.2 PRE-COMBUSTION FUEL SOURCE TESTS

The fuel stockpiles were tested for arsenic and PCDD/F to aid in proportioning the fuel components for each of the three runs of the Stratton and Livermore Falls trial burns. For the Stratton trial burn, this testing was done in conjunction with Phase I and the results are presented in Table 2.

The results for Livermore Falls are presented in Tables 5 and 6. The initial sample from the CDD stockpile was divided into two subsamples for testing (Composite Split A and B). Both subsamples had arsenic levels that were higher than expected. As a result, an additional ten samples were taken, five from the surface of the stockpile and five from a depth below the surface. The results showed that the arsenic concentrations were highly variable, ranging from a low of 2.1 mg/kg to a high of 201 mg/kg. It is likely that the concentration is influenced by the amount of CCA treated wood in a sample. For the purposes proportioning the fuel blends, the result from Composite Split A and B were first averaged to represent the arsenic concentration in the initial sample. Then, the average of the composite sample and the ten additional samples was computed yielding an arsenic concentration of 54.7 mg/kg. This was similar to the arsenic concentration of the CDD fuel pile for the Stratton trial burn (63 mg/kg). The PCDD/F reporting TEQ of the CDD stockpiles for the two trial burns were also similar (40 pg/g for Stratton vs. 35 pg/g for Livermore Falls).

Table 5. Arsenic results on fuel source stockpiles for Livermore Falls Trial Burn.

	<b>Sample Identification</b>	<b>Sample Date</b>	<b>Total As (mg/kg)</b>	<b>Percent Solids</b>
<b>CDD Stockpile</b>	<b>Composite Split A</b>	05/19/04	194	79.79
	<b>Composite Split B</b>	05/19/04	201	79.57
	<b>1-A-S</b>	05/25/04	15.0	74.72
	<b>1-B-S</b>	05/25/04	2.1	73.09
	<b>1-C-S</b>	05/25/04	3.2	78.41
	<b>2-A-S</b>	05/25/04	28	74.02
	<b>2-B-S</b>	05/25/04	1.5	73.61
	<b>1-A-D</b>	05/25/04	176	76.65
	<b>B-1-D</b>	05/25/04	30	79.11
	<b>1-C-D</b>	05/25/04	119	79.14
	<b>C-2-D</b>	05/25/04	21	77.66
	<b>B-3-D</b>	05/25/04	54	77.99
	<b>CCA Treated Stockpile</b>	05/19/04	1394	83.22

Table 6. PCDD/F results on fuel source stockpiles for Livermore Falls Trial Burn.

<b>Fuel Type</b>	<b>Reporting TEQ (pg/g)</b>
<b>Blank</b>	0.060
<b>Clean Wood</b>	0.31
<b>CDD</b>	35
<b>Pentachlorophenol Treated</b>	9248*

\*Based on preliminary results provided by Eno River Labs; final results reported by Eno River had a TEQ that was unreasonably low by a factor of 100 most likely due to an error in calculating the dilution factor. The preliminary results are given in Table 6 and were used in proportioning the fuel blends.

### 3.3 PROPORTIONING FUEL BLENDS

The pre-combustion test results (Tables 2, 5, and 6) were used to proportion the fuel blends to approximate the arsenic and PCDD/F concentrations given in Table 4. Run no. 1 contains only clean wood, so no blending was required. For the clean wood as delivered, it was possible to meet the target PCDD/F concentrations. However, the clean wood arsenic concentration was 0.8 mg/kg for Stratton and 0.31 mg/kg for Livermore Falls so it was not possible to meet the target given in Table 4 for run no. 1.



For run no. 2, it was calculated that a blend of approximately 10% CDD with 90% clean wood was needed to achieve the target arsenic concentrations for both trial burns. To reach the target PCDD/F concentrations it was estimated that it was necessary to add 0.04% pentachlorophenol treated wood for Stratton and 0.13% pentachlorophenol treated wood for Livermore Falls.

For run no. 3, it was estimated that a 50%:50% blend of CDD and clean wood was needed to achieve the target arsenic concentrations for both trial burns. To reach the target PCDD/F concentrations it was estimated that it was necessary to add 0.25% pentachlorophenol treated wood for Stratton and 0.8% pentachlorophenol treated wood for Livermore Falls.

Blended stockpiles were created for run nos. 2 and 3. For run no. 2, this was done by adding one front-end loader bucket of CDD for every nine buckets of clean wood. In addition, a one-gallon scoop of pentachlorophenol treated wood was added for each 10 yd<sup>3</sup> loader bucket for Stratton and a two-gallon scoop for each 8 yd<sup>3</sup> loader bucket for Livermore Falls. In a similar manner for run no. 3, one loader bucket of CCD was added for each loader bucket of clean wood. In addition, a five-gallon scoop of pentachlorophenol treated wood was added for each 10 yd<sup>3</sup> loader bucket for Stratton and a fifteen-gallon scoop for each 8 yd<sup>3</sup> loader bucket for Livermore Falls. For run no. 1 no blending was necessary, so clean fuel from the clean fuel stockpile was fed directly into the fuel in-feed hopper.

Prior to the start of a sampling period for each run, the appropriate clean wood or blended fuel was burned in the plant for approximately three hours to purge the previous fuel from the in-feed system and the previous combustion byproducts from the discharge points.

### **3.4 COMBUSTION AND ELECTROSTATIC PRECIPITATOR PARAMETERS**

The plant combustion and electrostatic precipitator parameters were examined for significant deviations between trial burn days that could have affected the concentration of compounds in the combustion byproducts. This data is summarized in a report prepared by Boralex dated May, 2005<sup>4</sup>. The combustion parameters are recorded hourly. To facilitate the examination, the mean and standard deviation of each parameter were computed over the approximately 9 hour monitoring period for each trial run. The results were screened to determine the parameters that warranted further examination by computing the percent difference of the mean of an individual run from the average of that parameter for all three runs at a plant. If the deviation was greater than  $\pm 10\%$  from the average of all three runs, the parameter was examined further and is discussed in the following subsections.

The electrostatic precipitator parameters are recorded manually four times per day. This resulted in one or two sets of readings during each 9-hour monitoring period. At Stratton there are four electrostatic fields in the precipitator compared to three at

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<sup>4</sup>“Combustion Study Operational Data – Boralex Stratton Energy, Inc. (Dec. 2003) & Boralex Livermore Falls, Inc. (May/June 2004)”, Boralex, May, 2005.

Livermore Falls. The parameters were examined by the plant operators to determine if they were operating within normal ranges. The responses from the plant operators are discussed in the following subsections.

The plants monitor parameters related to power generation, steam turbines, feed water to the boiler, deaerator for the feedwater, economizer that preheats the feedwater, cooling towers, and plant operating efficiency. These parameters are unrelated to combustion of the fuel, operation of the electrostatic precipitators, and stack gas, so were not considered in this comparison.

### **3.4.1 Stratton**

For the Stratton trial burn the parameters for an individual run that deviated more than 10% from the mean of all three runs are the following: forced draft outlet air temperature (15.1% maximum difference), secondary air heater furnace inlet temperature (14.4% maximum difference), CO at induced draft fan after precipitator (23.8% maximum difference), opacity at stack (64.4% maximum difference), and boiler CO in lbs/MBTU (64.6% maximum difference). Of these, only the first two are input parameters that affect the characteristics of the burn. Given that the maximum difference is about 15%, it is unlikely that variations of the monitored input combustion parameters had a significant influence on the results of the Stratton trial burn.

The opacity at stack increased for each successive run (0.96% for control; 1.30% for low; and 2.75% for moderate). Particulate matter (PM) measurements by AirTox were incomplete, but available results show that the PM was higher for the moderate run than for the low run.

The remaining two parameters relate to CO and are results of the burn characteristics. Examination of the hourly readings for these parameters shows significant variability during a run. This resulted in coefficients of variation (standard deviation divided by mean) ranging from 35% to 210%. A comparison that takes into account the standard deviation showed, with a 95% confidence level, that the mean parameters for each run were statistically equal, except for the “CO at induced draft fan after precipitator” for the control and low runs.

The operation of the precipitators was evaluated by the plant manager, Stephen Hall. He stated in an e-mail dated April 26, 2005, that: “With the exception of a 3-hour period of time during day 2 [end of moderate run] of the combustion study in which we attempted to demonstrate compliance with our particulate matter (PM) limit while operating in a 3-field configuration of our 4-field precipitator, I have no reason to believe that the precipitator was deviated either intentionally or unintentionally from normal operation.” As will be discussed in Section 3.5.1, shutting off the fourth field could have resulted in increased arsenic emissions.

The moisture contents of the as-burned fuel for this study were 54.6%, 56.5%, and 50.6% for the control, low, and moderate runs, respectively. This indicates that the fuel was drier for the moderate run. Overall, the fuel was wetter than normal. Mr. Hall

reported that this required high amounts of air for combustion, combined with a leaking tubular air heater, resulting in high differential pressures across the dust collectors. The effect on the distribution of contaminants in the combustion by-products is unknown.

### **3.4.2 Livermore Falls**

For the Livermore trial burn the parameters for an individual run that deviated more than 10% from the mean all three runs are the following: forced draft fan discharge pressure (173.1% maximum difference), forced draft fan discharge temperature (13.7% maximum difference), and fuel use (12.4% maximum difference). The recorded “forced draft fan discharge pressure was recorded as zero for the entire control run and all but the last hourly reading of the low-run. For the moderate run, the value remained constant at 3.5. It is possible that this sensor was malfunctioning or that there was a real difference in this value between the runs. This difference in the two remaining parameters was less than 15% and is unlikely to have had a significant influence on the results of this study.

One page of the hourly data record for May 26, 2004 was missing. This page dealt with precipitator and stack gas parameters. Thus, the comparison of burn characteristics for the Livermore Falls trial burn is incomplete. However, the data for June 16 and 17, 2004 shown that the precipitator and stack gas parameters differed from the mean of the two runs by less than 12%.

The hand-written logs of precipitator field operation could indicate that field #1 was off for the control run on May 26, 2004 and that field #3 was off for the low run on June 16, 2004. However, Mr. Michael Daigle from the Livermore Falls plants states that to the best of his knowledge for May 26, 2004, the precipitator “was operating under normal parameters”.

The fuel moisture contents are typically measured daily by the plant operators. It was reported as 38.0% for the control run, 30.8% for the low run, and 30.8% for the moderate run. For comparison, the moisture contents of the as-burned fuel made for this study were 40.8%, 40.0%, and 32.9%, for the control, low, and moderate runs, respectively. The latter results are considered to be more reliable since they were based on composite samples taken over the duration of the measurement period. They indicate that the fuel was drier for the moderate run. Comparing to the Stratton results shows that the fuel for the Livermore Falls trial burn was significantly drier.

## **3.5 CHEMICAL ANALYSIS OF AS-BURNED FUEL AND COMBUSTION BYPRODUCTS**

The as-combusted fuel, fly ash, and bottom ash were tested for arsenic, copper, total chlorine, soluble chlorine, and PCDD/F. These results were transmitted to the University of Maine in electronic format and a summary is included in this report. The stack gas was tested for arsenic and PCDD/F. These results were transmitted to the University of Maine in paper form by Air Tox Environmental Company, Inc. (Air Tox). A summary of these results is also presented in this report. Air Tox reports dated January 2004 and June 2004 should be consulted for a detailed presentation of the stack gas results. Additional

The results for each compound monitored in this study are presented in the following subsections.

### 3.5.1 Arsenic

The analytical results for arsenic are presented in Tables 7 and 8. By comparing the average arsenic concentrations in the fuel with the targets in Table 4, it is seen that the arsenic in run no. 1 for both trials was higher than the target by a factor of about 20. For Stratton run no. 2 the arsenic concentration was about equal to the target. However, for Stratton run no. 3 and Livermore run nos. 2 and 3 the as-burned arsenic concentration was less than the target value.

To better understand the fate of arsenic that was input into the boiler, the arsenic concentrations in Tables 7 and 8 were converted into the rate in kg/hr that arsenic was input as fuel and then output in the fly ash, bottom ash, and stack gas. For the all but the stack gas, this was done using the average hourly fuel consumption and the hourly production of fly ash and bottom ash as estimated by Boralex (see Tables 9 and 10). The total weights were multiplied by the percent solids determined by Maine Environmental Laboratory to obtain the fuel and combustion by-product rates based on solids weight in units of kg/hr as shown in Tables 9 and 10. The fuel input, fly ash generation, and bottom ash generation rates were multiplied by the respective arsenic concentrations resulting in the arsenic rates shown in Tables 11 and 12. The arsenic output rate in the stack gas given by AirTox are also shown in Tables 11 and 12. The sum of the arsenic output in the combustion by-products was computed and compared to the arsenic input in the fuel. A sample calculation is shown in Appendix C. For each run, the output exceeded the input by a large margin as shown in the last column of Tables 11 and 12. The reason for this discrepancy could not be determined.

There is a general trend that as the arsenic input increases, the arsenic output increases as shown in Figures 10 and 11. For the Stratton fly ash the trend was relatively uniform. For the Stratton bottom ash, the arsenic output was a little lower for the second run as compared to the first run. For the Stratton stack gas the trend is concave up. However, one of the precipitator fields was off for the latter part of run no. 3 and this may have been responsible for an increase in arsenic in the stack gas as shown for the Air 3 sample in Table 7. For each of the Livermore Falls combustion by-products there was a significant increase between the data points for the control and low runs. Examination of Table 8 shows that the arsenic concentration in Fly Ash A was approximately double that of Fly Ash B. The Fly Ash A and B samples were composites made by alternately depositing scoops of fly ash into the A and B containers, they were essentially taken over the same time period. Thus, there is no ready explanation for the difference between the arsenic concentrations in the Fly Ash A and B samples. The bottom ash showed a general trend of increasing arsenic output with increasing input. The arsenic output for each of the by-products for the moderate Livermore Falls run was higher than for the control run for each of the combustion by-products. Some of the observed behavior for the stack gas at Livermore Falls may have been influenced by precipitator field #1 possibly being off during run no. 1 and precipitator field #3 being off during run no. 2.

Table 7. Stratton trial burn arsenic results.

	FUEL A (mg/kg)	FUEL B (mg/kg)	<b>FUEL AVG. (mg/kg)</b>	FLY ASH A (mg/kg)	FLY ASH B (mg/kg)	<b>F.A. AVG. (mg/kg)</b>	<b>BOTTOM ASH (mg/kg)</b>	AIR 1 (mg/dscm)	AIR 2 (mg/dscm)	AIR 3 (mg/dscm)	<b>AIR AVG. (mg/dscm)</b>
As- Control	1.7	1.8	<b>1.8</b>	70	99	<b>84.5</b>	<b>25</b>	0.000759	0.000649	0.000731	<b>0.000713</b>
As-Low	2.8	8.7	<b>5.8</b>	175	203	<b>189</b>	<b>21</b>	0.00196	0.00267	0.00194	<b>0.00219</b>
As-Mod	7.9	15.1	<b>11.5</b>	628	553	<b>590.5</b>	<b>67</b>	0.0126	0.0042	0.0679	<b>0.0282</b>

Table 8. Livermore Falls trial burn arsenic results.

	FUEL A (mg/kg)	FUEL B (mg/kg)	<b>FUEL AVG. (mg/kg)</b>	FLY ASH A (mg/kg)	FLY ASH B (mg/kg)	<b>F.A. AVG. (mg/kg)</b>	<b>BOTTOM ASH (mg/kg)</b>	AIR 1 (mg/dscm)	AIR 2 (mg/dscm)	AIR 3 (mg/dscm)	<b>AIR AVG. (mg/dscm)</b>
As- Control	2.50	1.70	<b>2.1</b>	125	134	<b>129.5</b>	<b>15.4</b>	0.042	0.025	0.025	<b>0.031</b>
As-Low	3.80	3.20	<b>3.5</b>	632	336	<b>484</b>	<b>75</b>	0.121	0.123	0.117	<b>0.120</b>
As-Mod	13.20	8.40	<b>10.8</b>	537	561	<b>549</b>	<b>93</b>	0.072	0.056	0.058	<b>0.062</b>

Table 9. Consumption of fuel and production of fly and bottom ashes for the Stratton trial burn.

RUN	TOTAL WEIGHT			PERCENT SOLIDS			SOLIDS WEIGHT		
	FUEL (ton/hr)	FLY ASH (ton/hr)	BOTTOM ASH (ton/hr)	FUEL (%)	FLY ASH (%)	BOTTOM ASH (%)	FUEL (kg/hr)	FLY ASH (kg/hr)	BOTTOM ASH (kg/hr)
<b>Control</b>	53.4	1.7	1.7	45.4	69.0	83.0	21996	1063	1281
<b>Low</b>	49.9	1.6	1.6	43.5	70.9	81.7	19713	1029	1186
<b>Moderate</b>	54.2	1.8	1.8	49.4	69.8	80.8	24295	1140	1320

Table 10. Consumption of fuel and production of fly and bottom ashes for the Livermore Falls trial burn.

RUN	TOTAL WEIGHT			PERCENT SOLIDS			SOLIDS WEIGHT		
	FUEL (ton/hr)	FLY ASH (ton/hr)	BOTTOM ASH (ton/hr)	FUEL (%)	FLY ASH (%)	BOTTOM ASH (%)	FUEL (kg/hr)	FLY ASH (kg/hr)	BOTTOM ASH (kg/hr)
<b>Control</b>	44.7	1.52	2.28	59.2	72.9	93.1	24013	1005	1925
<b>Low</b>	49.6	1.69	2.52	60.0	78.7	89.7	26978	1207	2051
<b>Moderate</b>	50.3	1.71	2.57	67.1	73.6	90.4	30619	1141	2108

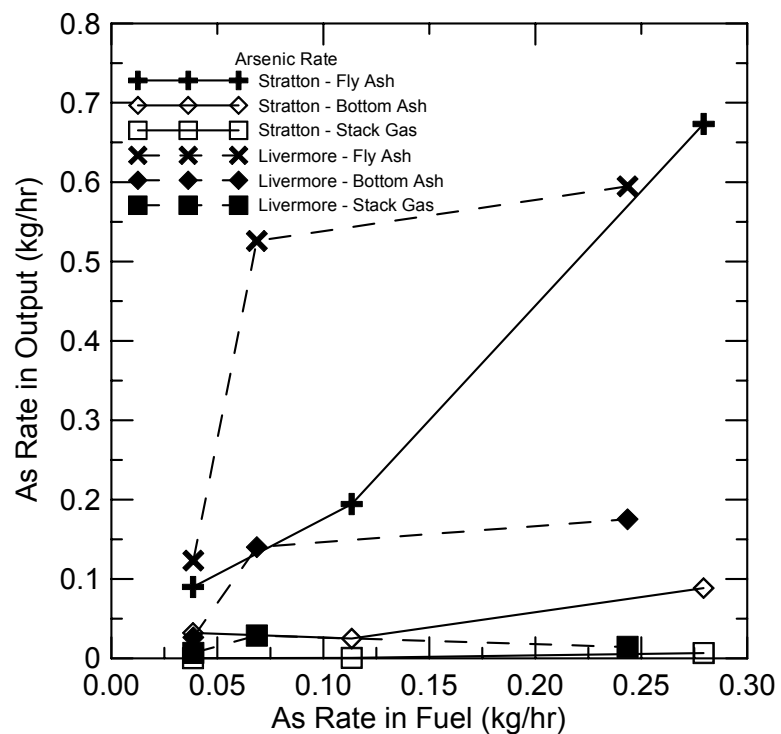


Figure 10. Rate of arsenic in output in combustion by-products versus arsenic rate input in fuel.

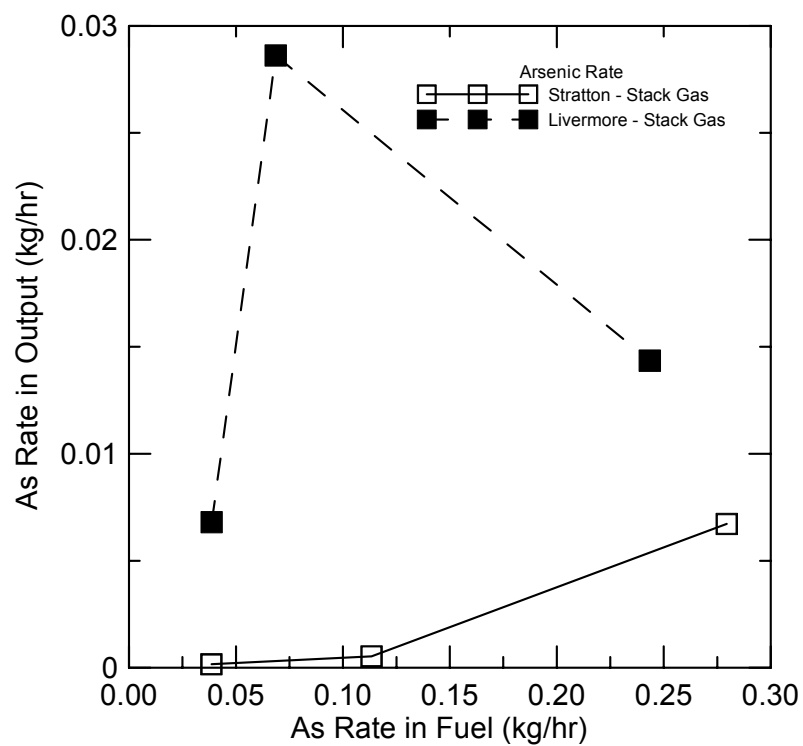


Figure 11. Rate of arsenic in output in combustion by-products versus arsenic rate input in fuel.

Comparison of the three output components in Tables 11 and 12 shows that the fly ash contains the majority of the arsenic. The fate of the arsenic is shown graphically in Figures 12 and 13. For Stratton 73.6% to 88.4% of the arsenic is contained in the fly ash. For Livermore Falls the fly ash contains 74.9% to 78.1% of the arsenic. This percentage appears to be independent of the level of arsenic input in the fuel. The stack gas for the Stratton trial burn contained a lower percentage of the arsenic than the Livermore Falls trial burn (0.13% to 0.87% for Stratton compared to 1.72% to 4.08% for Livermore Falls). The concentration of arsenic in the Stratton stack gas was also less than for Livermore Falls as shown in Tables 7 and 8.

The arsenic concentration in the stack gas shown in Tables 7 and 8, exceed the maximum ambient air guideline (MAAG) for arsenic ( $2 \times 10^{-6}$  mg/dscm) recommended by the Maine Bureau of Health<sup>5</sup>. However, this comparison ignores the mixing of the stack gas with the atmosphere and resulting dilution before coming into contact with a human receptor. These effects were considered by ambient air quality impact dispersion modeling performed by the Maine DEP Bureau of Air Quality included in Appendix D. The modeling was based on the highest arsenic discharge rates in the stack gas observed in each of the trials. This corresponded to the moderate run for the Stratton trial burn and the low run for the Livermore Falls trial burn. Based on the modeling, MDEP concluded that based on “worst case ambient air quality results from the Livermore Falls facility were only 30% of the MAAG value for arsenic” and “in the case of the Stratton facility, the worst case impact levels were 3.5% of the MAAG value for arsenic.”

The arsenic concentration in the fly and bottom ashes shown in Tables 7 and 8, exceeds the screening standards for beneficial use (5.375 mg/kg) given in Chapter 418, Beneficial Use of Solid Waste. Thus, further study would be required be needed to develop beneficial reuse of these ashes.

Table 11. Input and output of arsenic for Stratton trial burn.

<b>RUN</b>	<b>FUEL (kg/hr)</b>	<b>FLY ASH (kg/hr)</b>	<b>BOTTOM ASH (kg/hr)</b>	<b>STACK GAS (kg/hr)</b>	<b>OUTPUT SUM (kg/hr)</b>	<b>% DIFF</b>
<b>Control</b>	0.038	0.090	0.032	1.587E-04	0.122	217%
<b>Low</b>	0.113	0.194	0.025	5.272E-04	0.220	94%
<b>Moderate</b>	0.279	0.673	0.088	6.717E-03	0.768	175%

Table 12. Input and output of arsenic for Livermore Falls trial burn.

<b>RUN</b>	<b>FUEL (kg/hr)</b>	<b>FLY ASH (kg/hr)</b>	<b>BOTTOM ASH (kg/hr)</b>	<b>STACK GAS (kg/hr)</b>	<b>OUTPUT SUM (kg/hr)</b>	<b>% DIFF</b>
<b>Control</b>	0.050	0.130	0.030	6.798E-03	0.167	230%
<b>Low</b>	0.094	0.584	0.154	2.862E-02	0.766	712%
<b>Moderate</b>	0.331	0.626	0.196	1.435E-02	0.837	153%

<sup>5</sup> Maine Bureau of Health, “Ambient Air Guidelines,” Environmental Health Unit, Bureau of Health, Department of Human Services, April, 2004.



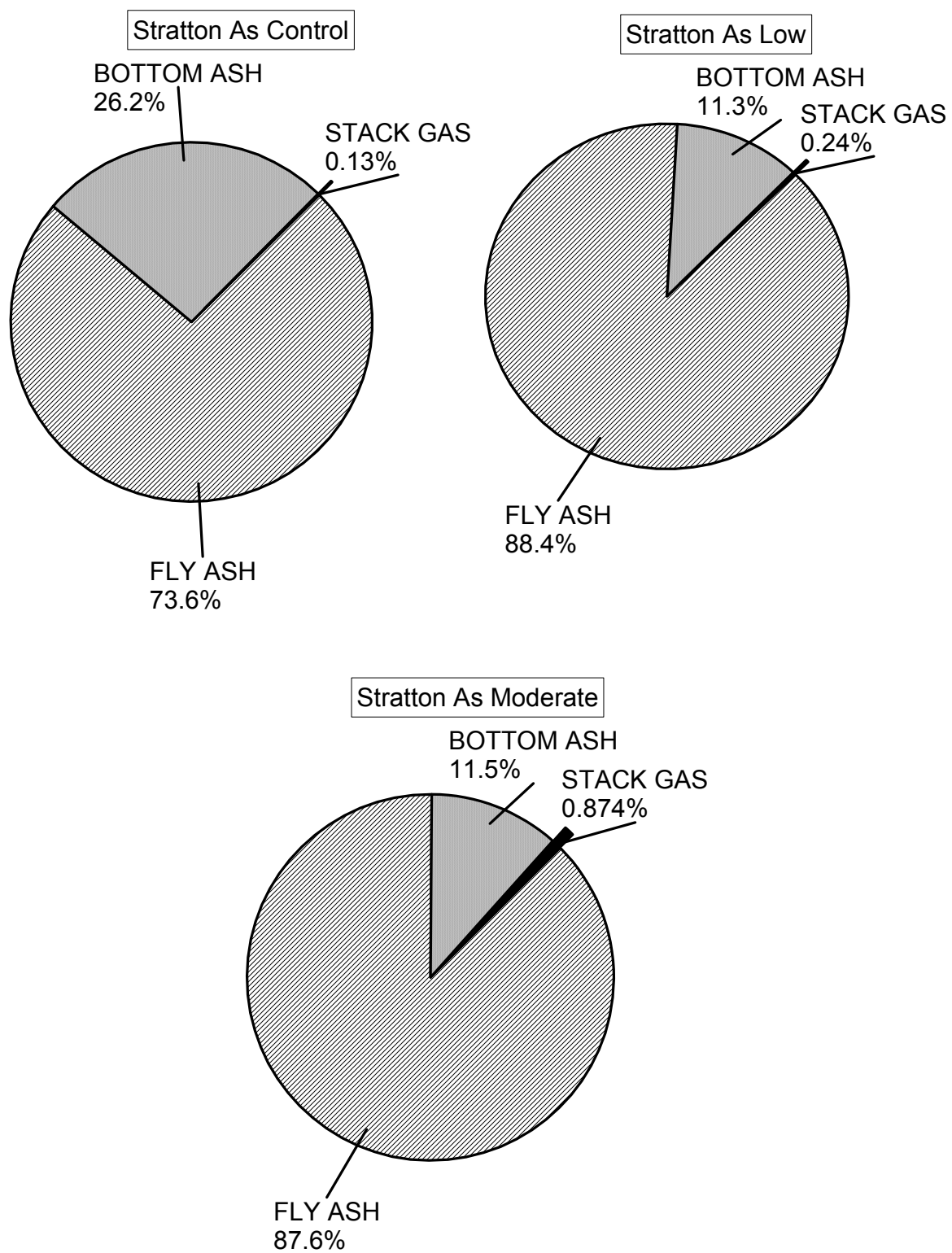


Figure 12. Distribution of arsenic in combustion by-products for Stratton trial burn.

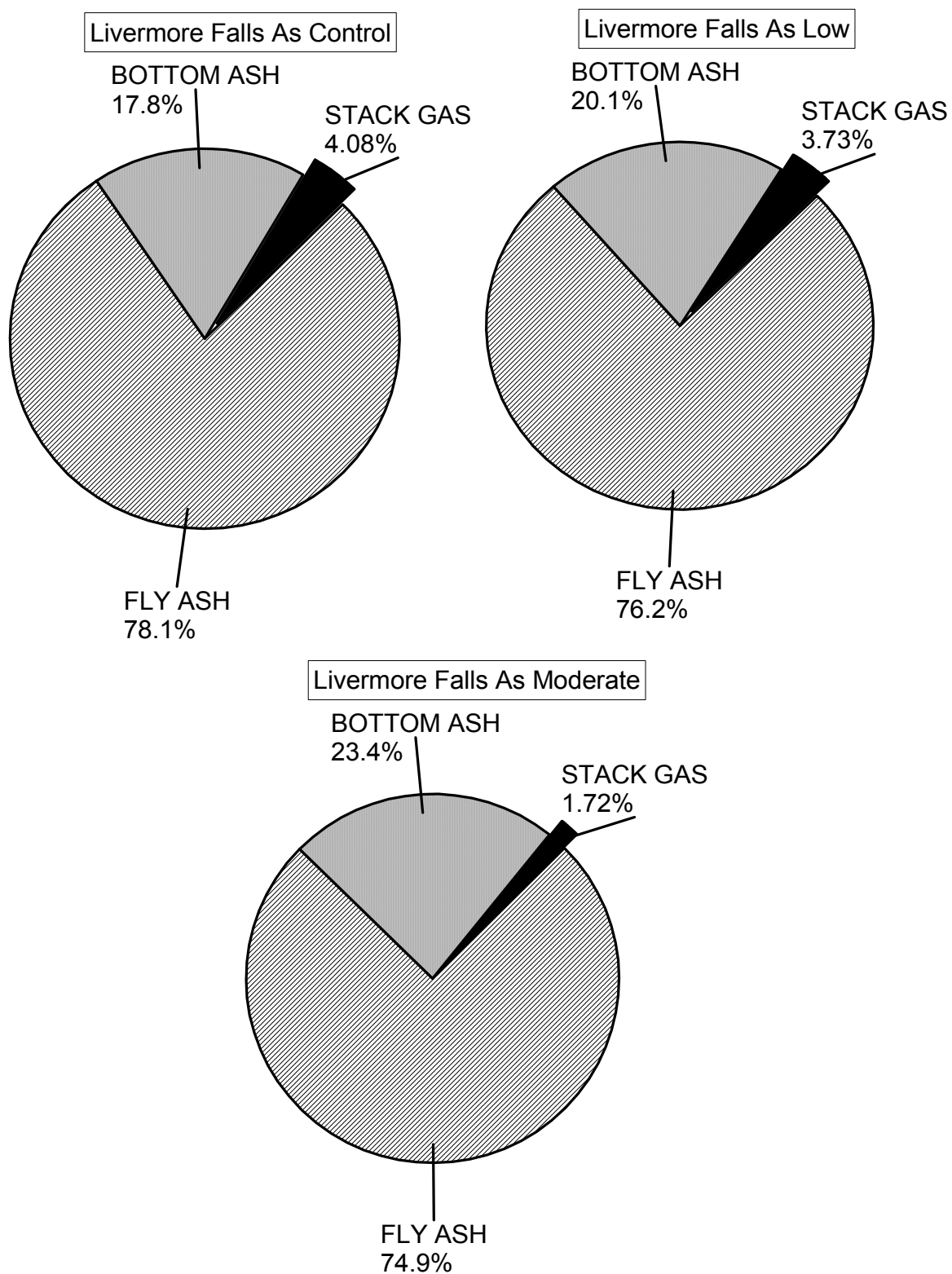


Figure 13. Distribution of arsenic in combustion by-products for Livermore Falls trial burn.

### 3.5.2 Copper

The analytical results for copper are presented in Tables 13 and 14. Copper was not included in the stack gas monitoring program so only the results for the solid components are presented. The average copper concentration in the fuel for comparable runs in the two trial burns was similar. Likewise, the average copper concentration in the fly and bottom ashes were similar with the values differing by no more than a factor of 2.

To better understand the fate of copper that was input into the boiler, the concentrations in Tables 13 and 14 were converted into the rate in kg/hr that copper was input as fuel and then output in the fly ash and bottom ash. The calculation procedure was discussed in Section 3.4.1. The results in units of kg/hr are shown in Tables 15 and 16. The sum of the copper output in the fly ash and bottom ash was computed and compared to the amount input in the fuel. The output ranged from 47% less than to 131% greater than the input. This comparison does not include copper that may have been present in the stack gas.

Comparison of the two output components in Tables 15 and 16 shows that the fly ash contains between 51.8% and 67.1% of the copper, with the balance contained in the bottom ash. This percentage was the same for both trial burns and appears to be independent of the level of copper input in the fuel.

There is a general trend that as the copper input increases, the copper output increases. The copper output rates in the fly ash and bottom ash are plotted versus the input rate in the fuel in Figure 14.

Table 13. Stratton trial burn copper results.

<b>RUN</b>	<b>FUEL A (mg/kg)</b>	<b>FUEL B (mg/kg)</b>	<b>FUEL AVG. (mg/kg)</b>	<b>FLY ASH A (mg/kg)</b>	<b>FLY ASH B (mg/kg)</b>	<b>FLY ASH AVG. (mg/kg)</b>	<b>BOTTOM ASH (mg/kg)</b>
<b>Control</b>	11	11	<b>11.0</b>	113	125	<b>119</b>	<b>51</b>
<b>Low</b>	12	45	<b>28.5</b>	172	175	<b>173.5</b>	<b>102</b>
<b>Moderate</b>	40	21	<b>30.5</b>	351	364	<b>357.5</b>	<b>288</b>

Table 14. Livermore Falls trial burn copper results.

<b>RUN</b>	<b>FUEL A (mg/kg)</b>	<b>FUEL B (mg/kg)</b>	<b>FUEL AVG. (mg/kg)</b>	<b>FLY ASH A (mg/kg)</b>	<b>FLY ASH B (mg/kg)</b>	<b>FLY ASH AVG. (mg/kg)</b>	<b>BOTTOM ASH (mg/kg)</b>
<b>Control</b>	5	5	<b>5.0</b>	93	121	<b>107</b>	<b>29</b>
<b>Low</b>	14	8	<b>11.0</b>	300	245	<b>272.5</b>	<b>108</b>
<b>Moderate</b>	24	15	<b>19.5</b>	494	558	<b>526</b>	<b>195</b>

Table 15. Input and output of copper for Stratton trial burn.

RUN	FUEL (kg/hr)	FLY ASH (kg/hr)	% IN FLY ASH	BOTTOM ASH (kg/hr)	% IN BOT. ASH	OUTPUT SUM (kg/hr)	% DIFF
Control	0.242	0.127	66.1%	0.065	33.9%	0.192	-21%
Low	0.562	0.178	59.5%	0.121	40.5%	0.299	-47%
Moderate	0.741	0.408	51.8%	0.380	48.2%	0.788	6%

Table 16. Input and output of copper for Livermore Falls trial burn.

RUN	FUEL (kg/hr)	FLY ASH (kg/hr)	% IN FLY ASH	BOTTOM ASH (kg/hr)	% IN BOT. ASH	OUTPUT SUM (kg/hr)	% DIFF
Control	0.092	0.102	67.1%	0.050	32.9%	0.152	65%
Low	0.216	0.296	59.4%	0.202	40.6%	0.498	131%
Moderate	0.440	0.570	60.8%	0.367	39.2%	0.937	113%

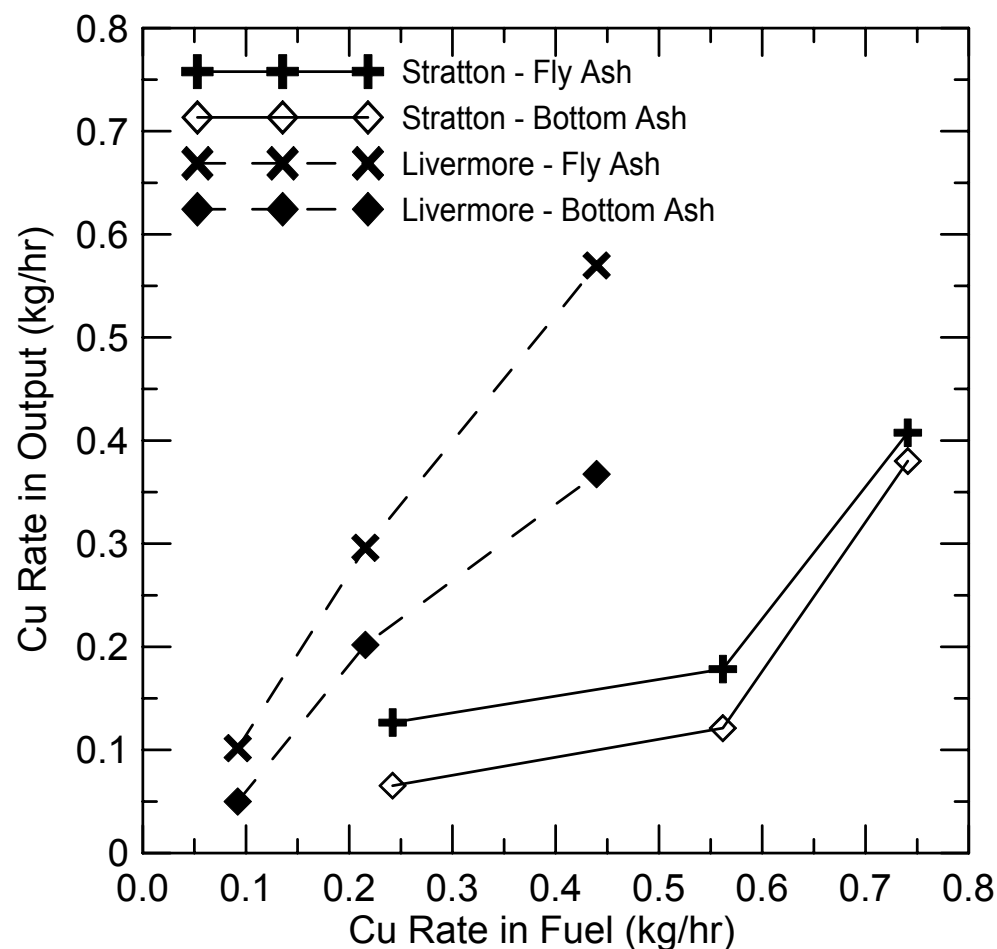


Figure 14. Rate of copper in output versus copper rate input in fuel.

The copper concentration in the fly and bottom ashes shown in Tables 13 and 14, is below the screening standards for beneficial use (1500 mg/kg) given in Chapter 418, Beneficial Use of Solid Waste.

### **3.5.3 Total Chlorine and Extractable Chloride**

Total chlorine and extractable chloride in the fuel and combustion by-products was examined because it could be a possible source of chlorine for the formation of PCDD/F. The total chlorine content, expressed as a percent of the total dry mass, is presented in Tables 17 and 18. The extractable chloride in mg/kg for Stratton is given in Table 19. Extractable chlorides were not determined for the Livermore Falls trial burn. The results for the fuel show that the total chlorine and extractable chloride content was highest for the clean fuel and tended to be lower for the low and moderate runs. The results expressed in kg/hr that was input in the fuel, and output in the fly and bottom ashes in Tables 21 through 22. The quantity of chlorine available in the fuel is very high in relation to the potential production of PCDD/F. Moreover, if the chlorine present in the fuel does in fact play a role in formation of PCDD/F, it appears that chlorine would be just as available in clean wood as in clean wood/CDD mixtures. Examining the total chlorine contents in the combustion by-products shows that over 96% of the output is contained in the fly ash (Tables 20 and 21). For extractable chlorides, the proportion in the fly ash varies significantly between the trials (Table 22). In all cases, the sum of the output in the fly and bottom ashes is less than that input in the fuel. This suggests that chlorine may be present in the stack gas

The total chlorine concentration in the fly and bottom ashes shown in Tables 17 and 18, in some cases exceeds the screening standards for beneficial use (0.975%) given in Chapter 418, Beneficial Use of Solid Waste. Thus, further study would be needed to develop beneficial reuse of these ashes.

Table 17. Stratton trial burn total chlorine content.

<b>RUN</b>	<b>FUEL A (%)</b>	<b>FUEL B (%)</b>	<b>FUEL AVG. (%)</b>	<b>FLY ASH A (%)</b>	<b>FLY ASH B (%)</b>	<b>FLY ASH AVG. (%)</b>	<b>BOTTOM ASH (%)</b>
<b>Control</b>	0.12	0.07	<b>0.10</b>	1.29	1.33	<b>1.31</b>	<b>0.02</b>
<b>Low</b>	0.07	0.08	<b>0.08</b>	0.9	0.99	<b>0.945</b>	<b>0.02</b>
<b>Moderate</b>	0.10	0.07	<b>0.09</b>	1.51	1.06	<b>1.285</b>	<b>0.05</b>

Table 18. Livermore Falls trial burn total chlorine content.

<b>RUN</b>	<b>FUEL A (%)</b>	<b>FUEL B (%)</b>	<b>FUEL AVG. (%)</b>	<b>FLY ASH A (%)</b>	<b>FLY ASH B (%)</b>	<b>FLY ASH AVG. (%)</b>	<b>BOTTOM ASH (%)</b>
<b>Control</b>	0.02	0.18	<b>0.10</b>	0.28	0.28	<b>0.28</b>	<b>0.04</b>
<b>Low</b>	0.02	0.03	<b>0.03</b>	0.01	0.01	<b>0.01</b>	<b>&lt;0.01</b>
<b>Moderate</b>	<0.01	0.03	<b>0.015</b>	0.16	0.03	<b>0.095</b>	<b>0.03</b>

Table 19. Stratton trial burn extractable chloride content.

<b>RUN</b>	<b>FUEL A (mg/kg)</b>	<b>FUEL B (mg/kg)</b>	<b>FUEL AVG. (mg/kg)</b>	<b>FLY ASH A (mg/kg)</b>	<b>FLY ASH B (mg/kg)</b>	<b>FLY ASH AVG. (mg/kg)</b>	<b>BOTTOM ASH (mg/kg)</b>
<b>Control</b>	552	378	<b>465</b>	3870	4320	<b>4095</b>	<b>23.4</b>
<b>Low</b>	476	361	<b>419</b>	1960	4260	<b>3110</b>	<b>31.8</b>
<b>Moderate</b>	456	319	<b>388</b>	4330	3710	<b>4020</b>	<b>101</b>

Table 20. Input and output of total chlorine for Stratton trial burn.

<b>RUN</b>	<b>FUEL (kg/hr)</b>	<b>FLY ASH (kg/hr)</b>	<b>% IN FLY ASH</b>	<b>BOTTOM ASH (kg/hr)</b>	<b>% IN BOT. ASH</b>	<b>OUTPUT SUM (kg/hr)</b>	<b>% DIFF</b>
<b>Control</b>	20.9	13.9	97.8	0.256	2.2%	14.2	-32%
<b>Low</b>	14.8	9.7	97.0	0.237	3.0%	10.0	-33%
<b>Moderate</b>	20.7	14.7	96.0	0.660	4.0%	15.3	-26%

Table 21. Input and output of soluble chloride for Stratton trial burn.

<b>RUN</b>	<b>FUEL (kg/hr)</b>	<b>FLY ASH (kg/hr)</b>	<b>% IN FLY ASH</b>	<b>BOTTOM ASH (kg/hr)</b>	<b>% IN BOT. ASH</b>	<b>OUTPUT SUM (kg/hr)</b>	<b>% DIFF</b>
<b>Control</b>	10.2	4.4	100%	0.030	0%	4.4	-57%
<b>Low</b>	8.2	3.2	100%	0.038	0%	3.2	-61%
<b>Moderate</b>	9.4	4.6	97.9%	0.133	2.1%	4.7	-50%

Table 22. Input and output of total chlorine for Livermore Falls trial burn.

<b>RUN</b>	<b>FUEL (kg/hr)</b>	<b>FLY ASH (kg/hr)</b>	<b>% IN FLY ASH</b>	<b>BOTTOM ASH (kg/hr)</b>	<b>% IN BOT. ASH</b>	<b>OUTPUT SUM (kg/hr)</b>	<b>% DIFF</b>
<b>Control</b>	18.4	2.7	80.6%	0.687	19.4%	3.3	-82%
<b>Low</b>	4.9	0.1	91.7%	<0.01	8.3%	0.1	-98%
<b>Moderate</b>	3.4	1.0	62.7%	0.565	37.3%	1.6	-53%

### 3.5.4 PCDD/F

The analytical results for PCDD/F expressed in terms of reporting TEQ are summarized in Tables 23 and 24. Analytical results for individual congeners are presented in Appendix B. By comparing the average PCDD/F reporting TEQ in Tables 23 and 24 in the fuel with the targets in Table 4, it is seen that the concentration in run no. 1 at Stratton met the target of < 4 pg/g. However, this concentration was exceeded for run no. 1 at Livermore Falls. For run no. 2 the concentration at Stratton was slightly below the target and at Livermore Falls was greater than the target by a factor of 1.8. For run no. 3 for the concentrations were less than the target values by a factor of 3 at Stratton and a factor of 1.3 at Livermore Falls.

To better understand the quantity of PCDD/F that was input to and output from the boilers, the concentrations in Tables 23 and 24 were converted into the rate in units of µg/hr. The calculation procedure was discussed in Section 3.4.1. The results in terms of

Table 23. Stratton trial burn PCDD/F reporting TEQ results.

	FUEL A (pg/g)	FUEL B (pg/g)	<b>FUEL AVG. (pg/g)</b>	FLY ASH A (pg/g)	FLY ASH B (pg/g)	<b>F.A. AVG. (pg/g)</b>	<b>BOTTOM ASH (pg/g)</b>	AIR 1 (ng/dscm)	AIR 2 (ng/dscm)	AIR 3 (ng/dscm)	<b>AIR AVG. (ng/dscm)</b>
Control	2.48	1.68	<b>2.1</b>	183.92	212.36	<b>198.14</b>	<b>0.22</b>	1.08E-02	1.06E-02	8.33E-03	<b>9.92E-03</b>
Low	10.53	13.99	<b>12.3</b>	125.74	204.17	<b>164.95</b>	<b>0.33</b>	8.46E-03	4.95E-03	1.42E-02	<b>9.21E-03</b>
Moderate	27.40	33.19	<b>30.3</b>	549.03	407.33	<b>478.18</b>	<b>1.50</b>	5.33E-02	2.81E-01	1.50E-01	<b>1.62E-01</b>

Table 24. Livermore Falls trial burn PCDD/F reporting TEQ results.

	FUEL A (pg/g)	FUEL B (pg/g)	<b>FUEL AVG. (pg/g)</b>	FLY ASH A (pg/g)	FLY ASH B (pg/g)	<b>F.A. AVG. (pg/g)</b>	<b>BOTTOM ASH (pg/g)</b>	AIR 1 (ng/dscm)	AIR 2 (ng/dscm)	AIR 3 (ng/dscm)	<b>AIR AVG. (ng/dscm)</b>
Control	11.41	10.25	<b>10.8</b>	124.86	137.17	<b>131.01</b>	<b>0.094</b>	1.52E-02	9.14E-03	7.45E-03	<b>1.06E-02</b>
Low	25.93	30.55	<b>28.2</b>	619.94	712.20	<b>666.07</b>	<b>0.0956</b>	1.21E-01	1.06E-01	8.40E-02	<b>1.04E-01</b>
Moderate	69.62	76.06	<b>72.8</b>	606.10	699.28	<b>652.69</b>	<b>12.1006</b>	5.39E-02	3.23E-02	3.90E-02	<b>4.17E-02</b>



reporting TEQ are given in Tables 25 and 26. The sum of the PCDD/F output in the fly ash, bottom ash, and stack gas was computed and compared to the input in the fuel. Based on reporting TEQ (Tables 25 and 26), the PCDD/F output rate varied from 65% below to 9% above the input rate, with the exception of the control run for Stratton where the output rate was 372% greater than the input rate. The reason for the latter result could not be determined.

Comparison of the three combustion by-products in Tables 25 and 26 shows that the fly ash contains the majority of the PCDD/F. This is shown graphically in Figures 15 and 16. The percentages are summarized in tabular form in Table 27. For Stratton 88.7% to 97.6% of the reporting TEQ is contained in the fly ash. For Livermore Falls the fly ash contains 95.5% to 98.1% of the reporting TEQ. The percent tended to decrease slightly as the PCDD/F content in the fuel increased. The percent of the PCDD/F contained in the bottom ash was small being less than 0.32% for five out of the six runs, with the exception being the Livermore Falls moderate run. Referring to Tables 23 and 24, the PCDD/F TEQ concentration in the bottom ash in five runs is less than 4.0 pg/g TEQ referenced under 1.H Prohibition of Chapter 418. Moreover, in these five runs the TEQ is less than the background level in clean wood fuel. With additional study to confirm the PCDD/F in the bottom ash, this could open the possibility that a beneficial use of bottom ash could be developed. For both trials, the highest percent in the bottom ash was observed for the moderate run. For the stack gas, the percent reporting TEQ ranged between 1.8% and 11.0%. At Stratton the highest percent was observed for the moderate run where as the lowest percent was observed for this run for the Livermore Falls trial burn. This suggests that the percent of the PCDD/F output in the stack gas is controlled by factors that are in addition to the PCDD/F input.

There is a general trend that as the PCDD/F input increases, the PCDD/F in the combustion by-products increases. The trends are nonlinear as shown in Figure 17 for fly ash and Figure 18 for bottom ash. This suggests that factors in addition to PCDD/F content in the input are important in controlling the PCDD/F in the output.

The PCDD/F concentration in the stack gas shown in Tables 23 and 24 exceed the maximum ambient air guideline (MAAG) for PCDD/F ( $3 \times 10^{-4}$  ng/dscm) recommended by the Maine Bureau of Health<sup>6</sup>. However, this comparison ignores the mixing of the stack gas with the atmosphere and resulting dilution before coming into contact with a human receptor. These effects were considered by ambient air quality impact dispersion modeling performed by the Maine DEP Bureau of Air Quality included in Appendix D. The modeling was based on the highest PCDD/F discharge rates in the stack gas observed in each of the trials. This corresponded to the moderate run for the Stratton trial burn and the low run for the Livermore Falls trial burn. Based on the modeling, MDEP concluded that based on “worst case ambient air quality results from the Livermore Falls facility were only ... 0.47% of the MAAG value for dioxin” and “in the case of the Stratton facility, the worst case impact levels were ... 0.24% of the MAAG value for dioxin.”

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<sup>6</sup> Maine Bureau of Health, *ibid.*

Table 25. Input and output of PCDD/F based on reporting TEQ for Stratton trial burn.

<b>RUN</b>	<b>FUEL AVG. (µg/hr)</b>	<b>FLY ASH AVG. (µg/hr)</b>	<b>BOTTOM ASH (µg/hr)</b>	<b>STACK GAS AVG. (µg/hr)</b>	<b>OUTPUT SUM (κg/hr)</b>	<b>% DIFF</b>
<b>Control</b>	45.8	210.7	0.3	4.9	215.9	372%
<b>Low</b>	241.7	169.7	0.4	4.7	174.8	-28%
<b>Moderate</b>	736.0	545.3	2.0	67.3	614.6	-16%

Table 26. Input and output of PCDD/F based on reporting TEQ for Livermore Falls trial burn.

<b>RUN</b>	<b>FUEL AVG. (µg/hr)</b>	<b>FLY ASH AVG. (µg/hr)</b>	<b>BOTTOM ASH (µg/hr)</b>	<b>STACK GAS AVG. (µg/hr)</b>	<b>OUTPUT SUM (µg/hr)</b>	<b>% DIFF</b>
<b>Control</b>	260.0	131.6	0.2	2.3	134.1	-48%
<b>Low</b>	761.8	803.6	0.2	24.4	828.2	9%
<b>Moderate</b>	2230.3	744.8	25.5	9.8	780.1	-65%

Table 27. Distribution of PCDD/F TEQ in the combustion by-products.

	<b>Combustion By-Product</b>	<b>Stratton</b>			<b>Livermore Falls</b>		
		<b>Control</b>	<b>Low</b>	<b>Moderate</b>	<b>Control</b>	<b>Low</b>	<b>Moderate</b>
<b>Reporting TEQ</b>	<b>Fly Ash</b>	97.6%	97.1%	88.7%	98.1%	97.0%	95.5%
	<b>Bottom Ash</b>	0.13%	0.22%	0.32%	0.14%	0.02%	3.27%
	<b>Stack Gas</b>	2.3%	2.7%	11.0%	1.8%	2.9%	1.3%

Note: Percentages may not add to exactly 100% due to rounding.

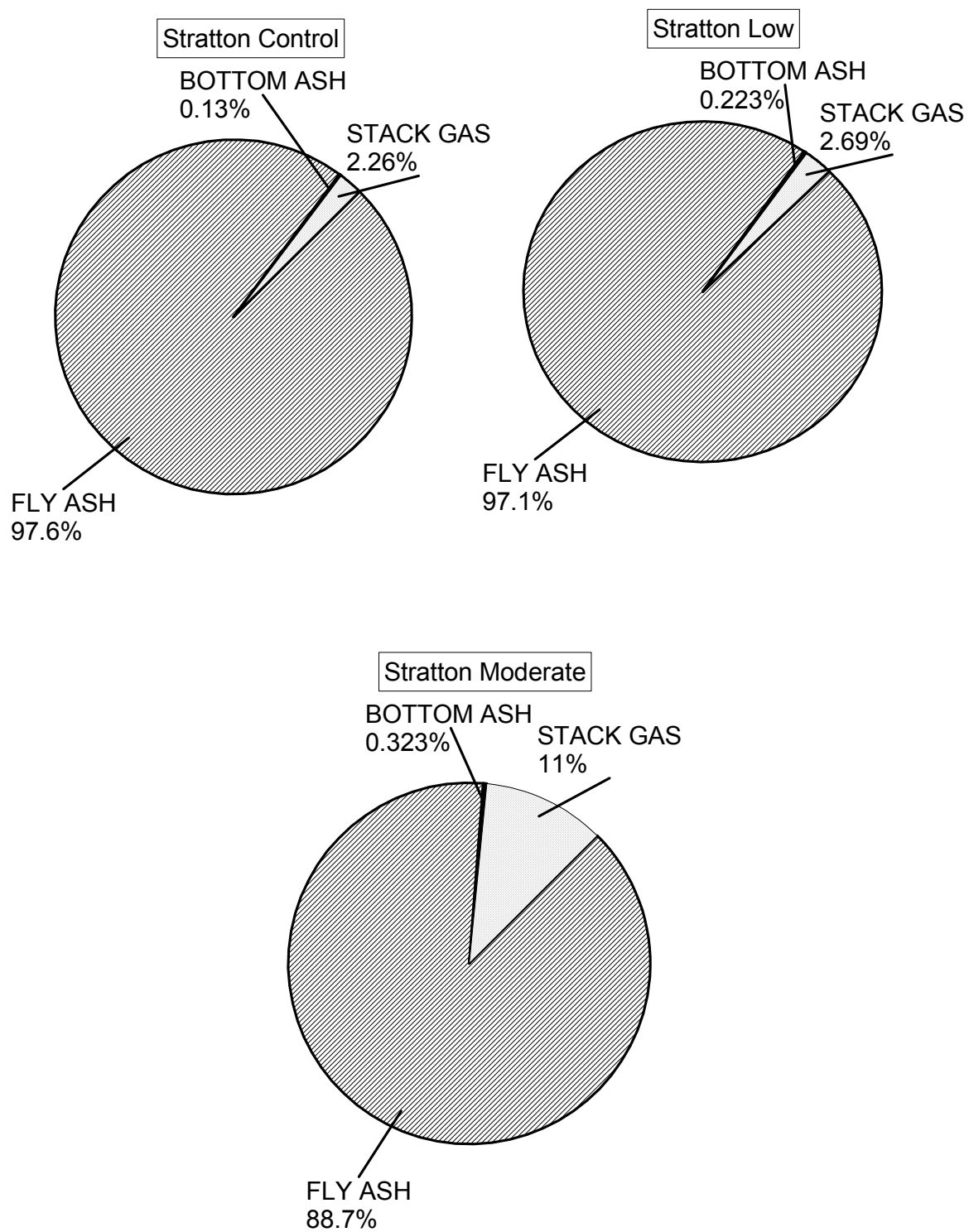


Figure 15. Distribution of PCDD/F reporting TEQ in combustion by-products for Stratton trial burn.

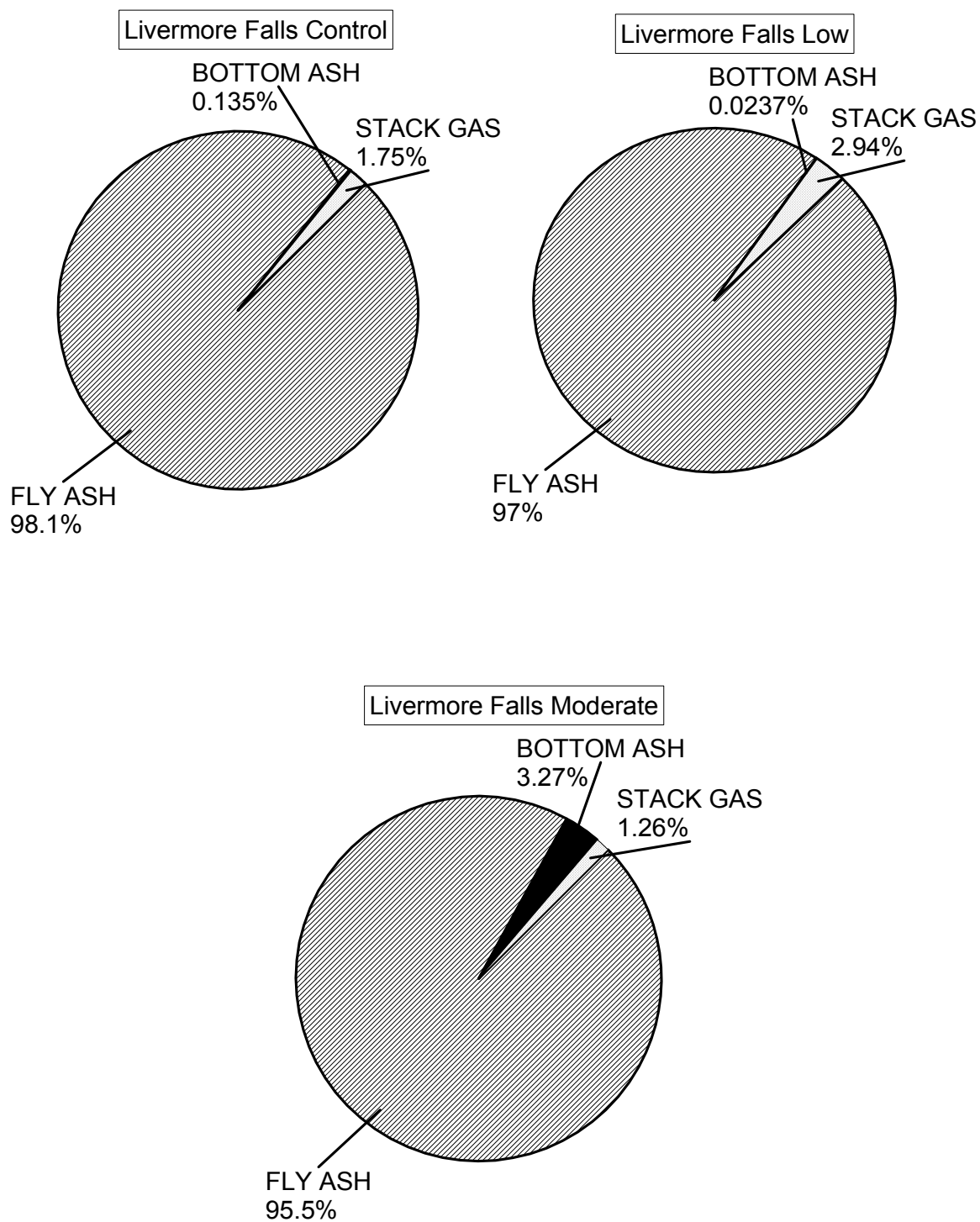


Figure 16. Distribution of PCDD/F reporting TEQ in combustion by-products for Livermore Falls trial burn.

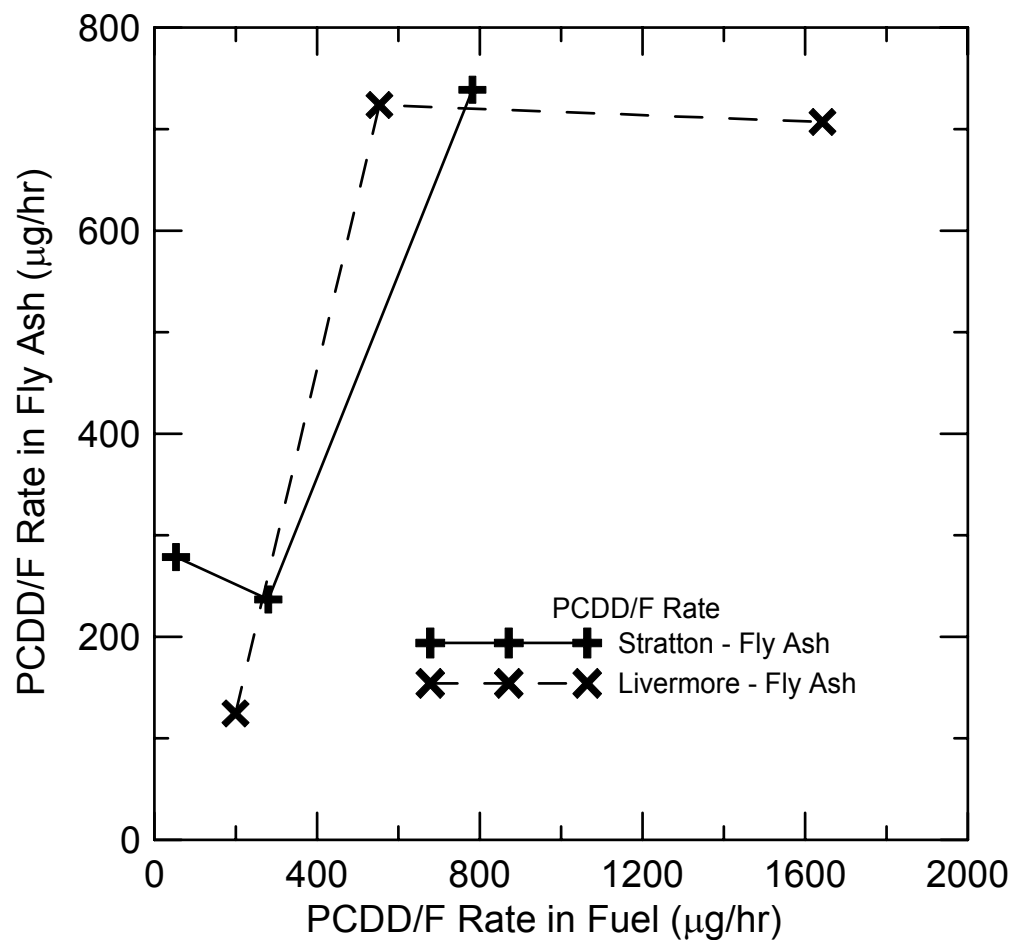


Figure 17. PCDD/F rate based on reporting TEQ in fuel versus output rate in fly ash.

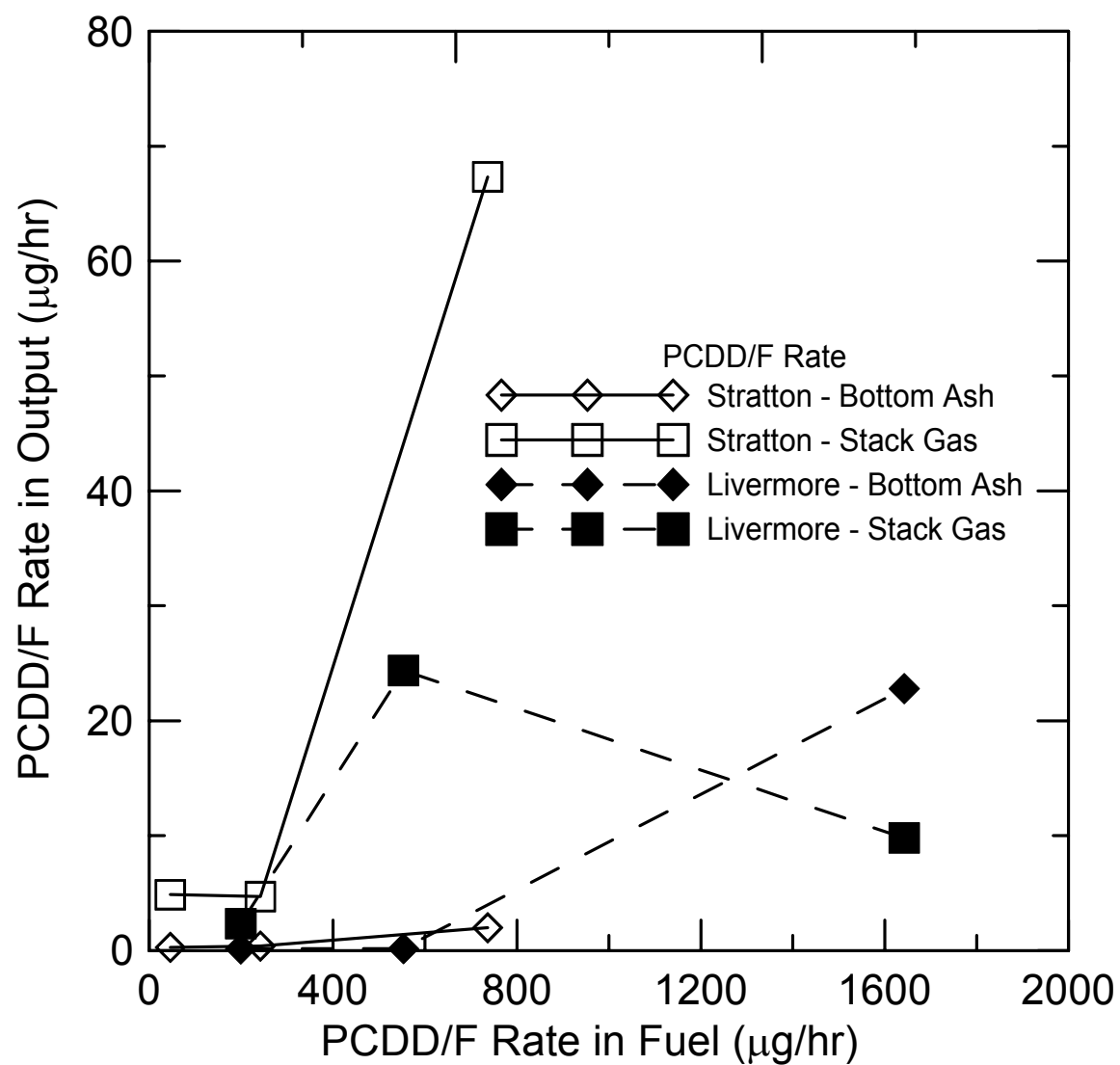


Figure 18. PCDD/F rate based on reporting TEQ in fuel versus output rate in bottom ash and stack gas.

#### 4. DISCUSSION AND SUMMARY

In the study of the physical composition of CDD, the CCA fraction of individual samples ranged from 0.1 to 5.4%. Moreover, the CCA fraction from duplicate municipal samples differed by a factor of two in some cases. This shows that the CCA content of small samples can be variable. On the average CCA fraction ranged from 1.0 to 2.0%. Overall, the average compositions of the municipal and commercial samples were similar.

The arsenic concentration of the CCA treated fractions were 2010 to 2409 mg/kg, which is very high relative to the other fractions. The arsenic content of the painted, burnable and minus #4 fractions varies between 30 and 778 mg/kg. For some fractions there are significant differences between the municipal and duplicated municipal samples again suggesting that the arsenic content in small samples can be highly variable. The contribution of the CCA fraction to the total arsenic present in the samples ranged from 14.0% to 56.3% with the balance of the arsenic coming from the burnable, painted, and minus #4 fractions. These results suggest that fractions other than the CCA wood contribute a significant portion of the total arsenic. Consideration should be given to the possibility that there is a source of arsenic other than CCA wood or that arsenic from CCA wood is transferred to other fractions during the demolition, grinding, sorting, and shipping processes.

The PCDD/F concentration of the fractions was generally above the 4.0 pg/g TEQ referenced under 1.H Prohibition of Chapter 418 TEQ. For the commercial and municipal samples, the minus #4 fractions had the highest reporting TEQ. For the commercial sample the minus #4 fraction contributed 93.2% of the reporting TEQ in the total sample, while this fraction accounted for 81.2% of the reporting TEQ of the municipal sample. For the municipal duplicate the minus #4, burnable, and painted fractions contributed comparable amounts of TEQ to the total sample. The source of the PCDD/F in the minus #4 fraction could not be determined.

In the trial burns, there was a general trend that as the arsenic input increases, the arsenic output in the combustion by-products increases. For the Stratton fly ash, the trend was relatively uniform. However, for the Stratton bottom ash, the arsenic output was a little lower for the low run as compared to the control run. For each of the Livermore Falls combustion by-products, there was a significant increase in arsenic output between the control and low runs. Moreover, the data showed that the arsenic concentration in the fly ash from the first half of the run was approximately double that of the second half of the run. The Fly Ash A and B samples were composites made by alternately depositing scoops of fly ash into the A and B containers, they were essentially taken over the same time period. Thus, there is no ready explanation for the difference between the arsenic concentrations in the Fly Ash A and B samples. The arsenic concentration in the stack gas for the moderate run at Stratton, and the control and low runs at Livermore Falls may have been affected by one of the precipitator fields being off for all, or a portion of, the measuring period.

The highest arsenic concentration in the stack gas for the Stratton trial burn was 0.0282 mg/dscm and for the Livermore Falls trial burn it was 0.120 mg/dscm. Modeling performed by MDEP (see Appendix D) showed that “the worst case ambient air impact results from the Livermore Falls facility were only 30% of the MAAG (Maximum Ambient Air Guideline) value for arsenic” and “in the case of the Stratton facility, the worst case impact levels were 3.5% of the MAAG value for arsenic.”

For Stratton, 73.6% to 88.4% of the arsenic in the combustion by-products was contained in the fly ash. For Livermore Falls the fly ash contained 74.9% to 78.1% of the arsenic. This percentage appears to be independent of the level of arsenic input in the fuel. The stack gas for the Stratton trial burn contained a lower percentage of the arsenic than the Livermore Falls trial burn (0.13% to 0.87% for Stratton compared to 1.72% to 4.08% for Livermore Falls).

Based on reporting TEQ, the PCDD/F output rate varied from 65% below to 9% above the input rate, with the exception of the control run for Stratton where the output rate was 372% greater than the input rate. The reason for the latter result could not be determined. Thus, for five out of the six runs, the PCDD/F output, based on reporting TEQ, ranged from below to roughly equivalent to the PCDD/F input.

There were general trends that as the PCDD/F input increases, the PCDD/F in the combustion by-products increases, however, the trends are nonlinear. The highest reporting TEQ in the stack gas for Stratton occurred in the moderate run (0.162 ng/dscm), whereas the highest value for Livermore Falls occurred in the low run (0.104 ng/dscm). Modeling performed by MDEP (see Appendix D) showed that “the worst case ambient air impact results from the Livermore Falls facility were only ... 0.47% of the MAAG (Maximum Ambient Air Guideline) value for dioxin” and “in the case of the Stratton facility, the worst case impact levels were ... 0.24% of the MAAG value for dioxin.”

For Stratton 88.7% to 97.6% of the reporting TEQ was contained in the fly ash. For Livermore Falls the fly ash contained 95.5% to 98.1% of the reporting TEQ. The percent of the PCDD/F contained in the bottom ash was small being less than 0.32% for five out of the six runs. For the stack gas, the percent reporting TEQ ranged between 1.8% and 11.0%. At Stratton the highest percent was observed for the moderate run where as the lowest percent was observed for this run for the Livermore Falls trial burn. This suggests that the percent of the PCDD/F output in the stack gas is controlled by factors that are in addition to the PCDD/F input alone.

The PCDD/F TEQ concentration in the bottom ash in five runs was less than 4.0 pg/g TEQ referenced under 1.H Prohibition of Chapter 418. Moreover, in these five runs the TEQ was less than the background level in clean wood fuel. With additional study to confirm the PCDD/F levels in the bottom ash, this could open the possibility that a beneficial use of bottom ash could be developed.

Levels of total chlorine in each of the runs was high relative to the PCDD/F concentrations. Moreover, the total chlorine levels decreased slightly as the percent



PCDD/F in the fuel blend increased. This suggests that availability of chlorine was not a controlling factor in the amount of PCDD/F in the combustion by-products.

The copper concentration in the fly and bottom ashes increased as the copper in the fuel increased. Given that the PCDD/F reporting TEQ input and output was roughly the same for several runs, it appears that the presence of increased copper levels does not promote an increase in PCDD/F reporting TEQ.



**APPENDIX A -  
RESULTS FOR PHASE I  
PHYSICAL ANALYSIS SAMPLES FROM  
FUEL SUPPLIERS**

Table A-1. Physical analysis of clean wood sample.

**Sieve Analysis**

Sample:	<b>CLEAN</b>	Analysis :	SML
Date:		Date:	10/24/2003
Taken By:		Checked:	DNH 10/27/2003
Notes:			

Tare (g):	2059.70
Tare+Initial Sample (g):	4862.90
Initial Sample (g):	2803.20

Sieve (in)	(mm)	Wt (g)	Wt Ret (g)	Wt Pass (g)	% Pass
3"	76.2	0.00	0.00	2798.50	100.0
#4	4.75	1684.40	1684.40	1114.10	39.8
Pan	N/A	1114.10	2798.50	0.00	0.0

Wt Total	2798.50
Wt Lost	4.70
% Lost	0.17

	Wt (g)	Percent (%)
Plastics	0.00	0.0
Painted Wood	0.00	0.0
Treated Wood	0.00	0.0
Burnable Wood, Paper & Cardboard	1663.70	59.9
Non-Burnable	0.00	0.0
Unclassified Mat'l Passing #4 Sieve	1114.10	40.1

Final Sample Total* (g):	2777.80
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\*NOTE: Final sample weight does not equal initial sample weight because of moisture lost during sample processing

**Ash Content of Unclassified Material Passing #4 Seive**

Total mass minus #4 (g)	1114.10	
Date	10/24/2003	
Tester	SML	
	<b>A</b>	<b>B</b>
Moisture content (%)	39.61	34.48
<b>Ash content based on moist mass (%)</b>	<b>12.23</b>	<b>10.77</b>
<b>Average based on moist mass (%)</b>	<b>11.50</b>	
Ash content based on dry mass (%)	17.07	14.48
Average	15.78	

Table A-2. Physical analysis of commercial sample C-1.

**Sieve Analysis**

Sample:	<b>C-1</b>	Analysis :	SML/JDL/JDP
Date:		Date:	10/24/2003
Taken By:		Checked:	DNH 10/27/2003
Notes:			

Tare (g):	2058.80
Tare+Initial Sample (g):	4506.60
Initial Sample (g):	2447.80

Sieve (in)	(mm)	Wt (g)	Wt Ret (g)	Wt Pass (g)	% Pass
3"	76.2	62.56	62.56	2376.80	97.4
#4	4.75	1862.80	1925.36	514.00	21.1
Pan	N/A	514.00	2439.36	0.00	0.0

Wt Total	2439.36
Wt Lost	8.44
% Lost	0.34

	Wt (g)	Percent (%)
Plastics	12.62	0.5
Painted Wood	168.59	7.1
Treated Wood	30.37	1.3
Burnable Wood, Paper & Cardboard	1641.30	68.9
Non-Burnable	16.08	0.7
Unclassified Mat'l Passing #4 Sieve	514.00	21.6

Final Sample Total* (g):	2382.96
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\*NOTE: Final sample weight does not equal initial sample weight because of moisture lost during sample processing

**Ash Content of Unclassified Material Passing #4 Seive**

Total mass minus #4 (g)	514.00	
Date	10/24/2003	
Tester	SML	
	<b>A</b>	<b>B</b>
Moisture content (%)	21.59	21.38
<b>Ash content based on moist mass (%)</b>	<b>13.71</b>	<b>18.47</b>
<b>Average based on moist mass (%)</b>	<b>16.09</b>	
Ash content based on dry mass (%)	16.67	22.41
Average	19.54	

Table A-3. Physical analysis of commercial sample C-2.

**Sieve Analysis**

Sample:	<b>C-2</b>	Analysis :	SML/JDL
Date:		Date:	10/23/2003
Taken By:		Checked:	DNH 10/27/2003
Notes:			

Tare (g):	2059.10
Tare+Initial Sample (g):	4250.20
Initial Sample (g):	2191.10

Sieve (in)	(mm)	Wt (g)	Wt Ret (g)	Wt Pass (g)	% Pass
3"	76.2	21.25	21.25	2163.60	99.0
#4	4.75	1817.80	1839.05	345.80	15.8
Pan	N/A	345.80	2184.85	0.00	0.0

Wt Total	2184.85
Wt Lost	6.25
% Lost	0.29

	Wt (g)	Percent (%)
Plastics	34.46	1.6
Painted Wood	211.51	9.9
Treated Wood	20.12	0.9
Burnable Wood, Paper & Cardboard	1492.80	69.6
Non-Burnable	40.10	1.9
Unclassified Mat'l Passing #4 Sieve	345.80	16.1

Final Sample Total* (g):	2144.79
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\*NOTE: Final sample weight does not equal initial sample weight because of moisture lost during sample processing

**Ash Content of Unclassified Material Passing #4 Seive**

Total mass minus #4 (g)	345.80	
Date	10/23/2003	
Tester	SML	
	<b>A</b>	<b>B</b>
Moisture content (%)	7.26	7.69
<b>Ash content based on moist mass (%)</b>	<b>21.80</b>	<b>16.33</b>
<b>Average based on moist mass (%)</b>	<b>19.07</b>	
Ash content based on dry mass (%)	23.39	17.58
Average	20.48	

Table A-4. Physical analysis of commercial sample C-3.

**Sieve Analysis**

Sample:	<b>C-3</b>	Analysis :	<b>SML</b>
Date:		Date:	10/20/2003
Taken By:		Checked:	
Notes:			

Tare (g):	920.50
Tare+Initial Sample (g):	3427.50
Initial Sample (g):	2507.00

Sieve (in)	(mm)	Wt (g)	Wt Ret (g)	Wt Pass (g)	% Pass
3"	76.2	0.00	0.00	2494.10	100.0
#4	4.75	1740.70	1740.70	753.40	30.2
Pan	N/A	753.40	2494.10	0.00	0.0

Wt Total	2494.10
Wt Lost	12.90
% Lost	0.51

	Wt (g)	Percent (%)
Plastics	15.07	0.6
Painted Wood	49.44	2.1
Treated Wood	21.26	0.9
Burnable Wood, Paper & Cardboard	1537.90	64.2
Non-Burnable	17.37	0.7
Unclassified Mat'l Passing #4 Sieve	753.40	31.5

Final Sample Total* (g):	2394.44
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\*NOTE: Final sample weight does not equal initial sample weight because of moisture lost during sample processing

**Ash Content of Unclassified Material Passing #4 Seive**

Total mass minus #4 (g)	753.40	
Date	10/22/2003	
Tester	SML	
	<b>A</b>	<b>B</b>
Crucible number	#10	#16
Moisture content (%)	11.84	11.92
<b>Ash content based on moist mass (%)</b>	<b>18.66</b>	<b>22.78</b>
<b>Average based on moist mass (%)</b>	<b>20.72</b>	
Ash content based on dry mass (%)	20.87	25.50
Average	23.18	

Table A-5. Physical analysis of municipal sample M-1.

**Sieve Analysis**

Sample:	M-1	Analysis :	SML/JDL
Date:		Date:	10/18/2003
Taken By:		Checked:	DNH 10/27/2003
Notes:			

Tare (g):	923.60
Tare+Initial Sample (g):	3802.10
Initial Sample (g):	2878.50

Sieve (in)	(mm)	Wt (g)	Wt Ret (g)	Wt Pass (g)	% Pass
3"	76.2	111.19	111.19	2754.50	96.1
#4	4.75	2317.70	2428.89	436.80	15.2
Pan	N/A	436.80	2865.69	0.00	0.0

Wt Total	2865.69
Wt Lost	12.81
% Lost	0.45

	Wt (g)	Percent (%)
Plastics	2.65	0.1
Painted Wood	200.82	7.2
Treated Wood	22.98	0.8
Burnable Wood, Paper & Cardboard	1978.46	71.3
Non-Burnable	133.59	4.8
Unclassified Mat'l Passing #4 Sieve	436.80	15.7

Final Sample Total* (g):	2775.30
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\*NOTE: Final sample weight does not equal initial sample weight because of moisture lost during sample processing

**Ash Content of Unclassified Material Passing #4 Seive**

Total mass minus #4 (g)	436.80	
Date	10/19/2003	
Tester	SML	
	<b>A</b>	<b>B</b>
Moisture content (%)	11.56	11.68
<b>Ash content based on moist mass (%)</b>	<b>17.53</b>	<b>23.85</b>
<b>Average based on moist mass (%)</b>	<b>20.69</b>	
Ash content based on dry mass (%)	19.56	26.64
Average	23.10	



Table A-6. Physical analysis of municipal sample M-2.

**Sieve Analysis**

Sample:	M-2	Analysis :	SML
Date:		Date:	10/14/2003
Taken By:		Checked:	DNH 10/27/2003
Notes:			

Tare (g):	905.60
Tare+Initial Sample (g):	3427.00
Initial Sample (g):	2521.40

Sieve (in)	(mm)	Wt (g)	Wt Ret (g)	Wt Pass (g)	% Pass
3"	76.2	0.00	0.00	2510.70	100.0
#4	4.75	2217.80	2217.80	292.90	11.7
Pan	N/A	292.90	2510.70	0.00	0.0

Wt Total	2510.70
Wt Lost	10.70
% Lost	0.42

	Wt (g)	Percent (%)
Plastics	9.90	0.4
Painted Wood	167.84	6.9
Treated Wood	54.18	2.2
Burnable Wood, Paper & Cardboard	1809.50	74.9
Non-Burnable	82.31	3.4
Unclassified Mat'l Passing #4 Sieve	292.90	12.1

Final Sample Total* (g):	2416.63
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\*NOTE: Final sample weight does not equal initial sample weight because of moisture lost during sample processing

**Ash Content of Unclassified Material Passing #4 Seive**

Total mass minus #4 (g)	292.90	
Date	10/16/2003	
Tester	SML	
	<b>A</b>	<b>B</b>
Moisture content (%)	20.30	18.41
<b>Ash content based on moist mass (%)</b>	<b>5.00</b>	<b>7.98</b>
<b>Average based on moist mass (%)</b>	<b>6.49</b>	
Ash content based on dry mass (%)	6.02	9.45
Average	7.73	

Table A-7. Physical analysis of municipal sample M-3.

**Sieve Analysis**

Sample:	<b>M-3</b>	Analysis :	SML
Date:		Date:	10/22/2003
Taken By:		Checked:	DNH 10/27/2003
Notes:			

Tare (g):	2058.80
Tare+Initial Sample (g):	5083.90
Initial Sample (g):	3025.10

Sieve (in)	(mm)	Wt (g)	Wt Ret (g)	Wt Pass (g)	% Pass
3"	76.2	0.00	0.00	3010.90	100.0
#4	4.75	2519.50	2519.50	491.40	16.3
Pan	N/A	491.40	3010.90	0.00	0.0

Wt Total	3010.90
Wt Lost	14.20
% Lost	0.47

	Wt (g)	Percent (%)
Plastics	3.14	0.1
Painted Wood	221.10	7.5
Treated Wood	19.23	0.7
Burnable Wood, Paper & Cardboard	2144.80	72.7
Non-Burnable	72.21	2.4
Unclassified Mat'l Passing #4 Sieve	491.40	16.6

Final Sample Total* (g):	2951.88
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\*NOTE: Final sample weight does not equal initial sample weight because of moisture lost during sample processing

**Ash Content of Unclassified Material Passing #4 Seive**

Total mass minus #4 (g)	491.40	
Date	10/23/2003	
Tester	SML	
	<b>A</b>	<b>B</b>
Moisture content (%)	17.46	17.44
<b>Ash content based on moist mass (%)</b>	<b>16.76</b>	<b>10.91</b>
<b>Average based on moist mass (%)</b>	<b>13.83</b>	
Ash content based on dry mass (%)	19.68	12.81
Average	16.25	

Table A-8. Physical analysis of municipal sample M-4.

**Sieve Analysis**

Sample:	M-4	Analysis :	JDL/SML/JDP
Date:		Date:	10/24/2003
Taken By:		Checked:	DNH 10/27/2003
Notes:			

Tare (g):	2058.90
Tare+Initial Sample (g):	4418.40
Initial Sample (g):	2359.50

Sieve (in)	(mm)	Wt (g)	Wt Ret (g)	Wt Pass (g)	% Pass
3"	76.2	0.00	0.00	2351.40	100.0
#4	4.75	1370.40	1370.40	981.00	41.7
Pan	N/A	981.00	2351.40	0.00	0.0

Wt Total	2351.40
Wt Lost	8.10
% Lost	0.34

	Wt (g)	Percent (%)
Plastics	1.95	0.1
Painted Wood	114.77	5.1
Treated Wood	6.01	0.3
Burnable Wood, Paper & Cardboard	1089.10	48.1
Non-Burnable	69.37	3.1
Unclassified Mat'l Passing #4 Sieve	981.00	43.4

Final Sample Total* (g):	2262.20
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\*NOTE: Final sample weight does not equal initial sample weight because of moisture lost during sample processing

**Ash Content of Unclassified Material Passing #4 Seive**

Total mass minus #4 (g)	981.00	
Date	10/24/2003	
Tester	SML	
	<b>A</b>	<b>B</b>
Moisture content (%)	4.60	5.77
<b>Ash content based on moist mass (%)</b>	<b>63.18</b>	<b>55.81</b>
<b>Average based on moist mass (%)</b>	<b>59.50</b>	
Ash content based on dry mass (%)	66.09	59.03
Average	62.56	

Table A-9. Physical analysis of municipal sample M-5.

**Sieve Analysis**

Sample:	<b>M-5</b>	Analysis :	<b>SML</b>
Date:		Date:	<b>10/23/2003</b>
Taken By:		Checked:	<b>DNH</b> <b>10/27/2003</b>
Notes:			

Tare (g):	<b>2059.30</b>
Tare+Initial Sample (g):	<b>4236.70</b>
Initial Sample (g):	<b>2177.40</b>

<b>Sieve (in)</b>	<b>(mm)</b>	<b>Wt (g)</b>	<b>Wt Ret (g)</b>	<b>Wt Pass (g)</b>	<b>% Pass</b>
<b>3"</b>	<b>76.2</b>	<b>0.00</b>	<b>0.00</b>	<b>2166.80</b>	<b>100.0</b>
<b>#4</b>	<b>4.75</b>	<b>1755.60</b>	<b>1755.60</b>	<b>411.20</b>	<b>19.0</b>
<b>Pan</b>	<b>N/A</b>	<b>411.20</b>	<b>2166.80</b>	<b>0.00</b>	<b>0.0</b>

Wt Total	<b>2166.80</b>
Wt Lost	<b>10.60</b>
% Lost	<b>0.49</b>

	<b>Wt (g)</b>	<b>Percent (%)</b>
Plastics	<b>4.52</b>	<b>0.2</b>
Painted Wood	<b>135.32</b>	<b>6.5</b>
Treated Wood	<b>47.74</b>	<b>2.3</b>
Burnable Wood, Paper & Cardboard	<b>1459.20</b>	<b>69.9</b>
Non-Burnable	<b>28.61</b>	<b>1.4</b>
Unclassified Mat'l Passing #4 Sieve	<b>411.20</b>	<b>19.7</b>

Final Sample Total* (g):	<b>2086.59</b>
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\*NOTE: Final sample weight does not equal initial sample weight because of moisture lost during sample processing

**Ash Content of Unclassified Material Passing #4 Seive**

Total mass minus #4 (g)	<b>411.20</b>	
Date	<b>10/23/2003</b>	
Tester	<b>SML</b>	
	<b>A</b>	<b>B</b>
Moisture content (%)	<b>14.50</b>	<b>16.02</b>
<b>Ash content based on moist mass (%)</b>	<b>7.33</b>	<b>7.07</b>
<b>Average based on moist mass (%)</b>	<b>7.20</b>	
Ash content based on dry mass (%)	<b>8.40</b>	<b>8.20</b>
Average	<b>8.30</b>	

Table A-10. Physical analysis of duplicate municipal sample DM-1.

**Sieve Analysis**

Sample:	DM-1	Analysis :	SML/JDL
Date:		Date:	10/18/2003
Taken By:		Checked:	DNH 10/27/2003
Notes:			

Tare (g):	1053.80
Tare+Initial Sample (g):	3355.40
Initial Sample (g):	2301.60

Sieve (in)	(mm)	Wt (g)	Wt Ret (g)	Wt Pass (g)	% Pass
3"	76.2	0.00	0.00	2294.80	100.0
#4	4.75	1744.90	1744.90	549.90	24.0
Pan	N/A	549.90	2294.80	0.00	0.0

Wt Total	2294.80
Wt Lost	6.80
% Lost	0.30

	Wt (g)	Percent (%)
Plastics	3.02	0.1
Painted Wood	142.25	6.4
Treated Wood	4.64	0.2
Burnable Wood, Paper & Cardboard	1505.20	67.6
Non-Burnable	21.64	1.0
Unclassified Mat'l Passing #4 Sieve	549.90	24.7

Final Sample Total* (g):	2226.65
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\*NOTE: Final sample weight does not equal initial sample weight because of moisture lost during sample processing

**Ash Content of Unclassified Material Passing #4 Seive**

Total mass minus #4 (g)	549.90	
Date	10/19/2003	
Tester	SML	
	<b>A</b>	<b>B</b>
Moisture content (%)	15.67	14.36
<b>Ash content based on moist mass (%)</b>	<b>20.33</b>	<b>29.45</b>
<b>Average based on moist mass (%)</b>	<b>24.89</b>	
Ash content based on dry mass (%)	23.51	33.68
Average	28.60	

Table A-11. Physical analysis of duplicate municipal sample DM-2.

**Sieve Analysis**

Sample:	DM-2	Analysis :	SML
Date:		Date:	10/17/2003
Taken By:		Checked:	DNH 10/27/2003
Notes:			

Tare (g):	907.00
Tare+Initial Sample (g):	3434.20
Initial Sample (g):	2527.20

Sieve (in)	(mm)	Wt (g)	Wt Ret (g)	Wt Pass (g)	% Pass
3"	76.2	0.00	0.00	2522.00	100.0
#4	4.75	2152.40	2152.40	369.60	14.7
Pan	N/A	369.60	2522.00	0.00	0.0

Wt Total	2522.00
Wt Lost	5.20
% Lost	0.21

	Wt (g)	Percent (%)
Plastics	2.00	0.1
Painted Wood	333.05	13.5
Treated Wood	134.25	5.4
Burnable Wood, Paper & Cardboard	1619.50	65.7
Non-Burnable	5.20	0.2
Unclassified Mat'l Passing #4 Sieve	369.60	15.0

Final Sample Total* (g):	2463.60
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\*NOTE: Final sample weight does not equal initial sample weight because of moisture lost during sample processing

**Ash Content of Unclassified Material Passing #4 Seive**

Total mass minus #4 (g)	369.60	
Date	10/17/2003	
Tester	SML	
	<b>A</b>	<b>B</b>
Moisture content (%)	17.14	16.72
<b>Ash content based on moist mass (%)</b>	<b>5.57</b>	<b>6.46</b>
<b>Average based on moist mass (%)</b>	<b>6.02</b>	
Ash content based on dry mass (%)	6.53	7.54
Average	7.04	

Table A-12. Physical analysis of duplicate municipal sample DM-3.

**Sieve Analysis**

Sample:	DM-3	Analysis :	JDL
Date:		Date:	10/21/2003
Taken By:		Checked:	DNH 10/27/2003
Notes:			

Tare (g):	909.70
Tare+Initial Sample (g):	3827.40
Initial Sample (g):	2917.70

Sieve (in)	(mm)	Wt (g)	Wt Ret (g)	Wt Pass (g)	% Pass
3"	76.2	0.00	0.00	2900.70	100.0
#4	4.75	2357.90	2357.90	542.80	18.7
Pan	N/A	542.80	2900.70	0.00	0.0

Wt Total	2900.70
Wt Lost	17.00
% Lost	0.58

	Wt (g)	Percent (%)
Plastics	31.35	1.1
Painted Wood	254.37	9.1
Treated Wood	23.35	0.8
Burnable Wood, Paper & Cardboard	1884.30	67.2
Non-Burnable	69.68	2.5
Unclassified Mat'l Passing #4 Sieve	542.80	19.3

Final Sample Total* (g):	2805.85
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\*NOTE: Final sample weight does not equal initial sample weight because of moisture lost during sample processing

**Ash Content of Unclassified Material Passing #4 Seive**

Total mass minus #4 (g)	542.80	
Date	10/22/2003	
Tester	SML	
	<b>A</b>	<b>B</b>
Moisture content (%)	12.77	16.30
<b>Ash content based on moist mass (%)</b>	<b>29.91</b>	<b>15.89</b>
<b>Average based on moist mass (%)</b>	<b>22.90</b>	
Ash content based on dry mass (%)	33.73	18.48
Average	26.11	

Table A-13. Physical analysis of duplicate municipal sample DM-4.

**Sieve Analysis**

Sample:	DM-4	Analysis :	SML/JDL/JDP
Date:		Date:	10/24/2003
Taken By:		Checked:	DNH 10/27/2003
Notes:			

Tare (g):	2060.00
Tare+Initial Sample (g):	5115.50
Initial Sample (g):	3055.50

Sieve (in)	(mm)	Wt (g)	Wt Ret (g)	Wt Pass (g)	% Pass
3"	76.2	0.00	0.00	3046.50	100.0
#4	4.75	1933.90	1933.90	1112.60	36.5
Pan	N/A	1112.60	3046.50	0.00	0.0

Wt Total	3046.50
Wt Lost	9.00
% Lost	0.29

	Wt (g)	Percent (%)
Plastics	5.02	0.2
Painted Wood	135.34	4.6
Treated Wood	3.41	0.1
Burnable Wood, Paper & Cardboard	1644.40	55.3
Non-Burnable	72.85	2.4
Unclassified Mat'l Passing #4 Sieve	1112.60	37.4

Final Sample Total* (g):	2973.62
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\*NOTE: Final sample weight does not equal initial sample weight because of moisture lost during sample processing

**Ash Content of Unclassified Material Passing #4 Seive**

Total mass minus #4 (g)	1112.60	
Date	10/24/2003	
Tester	SML	
	<b>A</b>	<b>B</b>
Moisture content (%)	27.59	21.30
<b>Ash content based on moist mass (%)</b>	<b>42.70</b>	<b>53.08</b>
<b>Average based on moist mass (%)</b>	<b>47.89</b>	
Ash content based on dry mass (%)	54.48	64.39
Average	59.44	



Table A-14. Physical analysis of duplicate municipal sample DM-5.

**Sieve Analysis**

Sample:	DM-5	Analysis :	SML
Date:		Date:	10/23/2003
Taken By:		Checked:	DNH 10/27/2003
Notes:			

Tare (g):	2059.00
Tare+Initial Sample (g):	3746.10
Initial Sample (g):	1687.10

Sieve (in)	(mm)	Wt (g)	Wt Ret (g)	Wt Pass (g)	% Pass
3"	76.2	29.54	29.54	1651.20	98.2
#4	4.75	1330.00	1359.54	321.20	19.1
Pan	N/A	321.20	1680.74	0.00	0.0

Wt Total	1680.74
Wt Lost	6.36
% Lost	0.38

	Wt (g)	Percent (%)
Plastics	6.10	0.4
Painted Wood	170.15	10.5
Treated Wood	70.94	4.4
Burnable Wood, Paper & Cardboard	1048.90	64.8
Non-Burnable	1.84	0.1
Unclassified Mat'l Passing #4 Sieve	321.20	19.8

Final Sample Total* (g):	1619.13
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\*NOTE: Final sample weight does not equal initial sample weight because of moisture lost during sample processing

**Ash Content of Unclassified Material Passing #4 Seive**

Total mass minus #4 (g)	321.20	
Date	10/23/2003	
Tester	SML	
	<b>A</b>	<b>B</b>
Moisture content (%)	18.52	17.24
<b>Ash content based on moist mass (%)</b>	<b>3.44</b>	<b>8.29</b>
<b>Average based on moist mass (%)</b>	<b>5.86</b>	
Ash content based on dry mass (%)	4.07	9.72
Average	6.90	



**APPENDIX B -  
RESULTS FOR PHASE II  
PCDD/F ANALYSES**

Table B-1. PCCD/F congeners for fuel and combustion by-products for Stratton trial burn.

Compound Name	Reporting TEQ Table 405.1	BLANK	CONTROL FUEL					LOW LEVEL FUEL					MODERATE LEVEL FUEL				
			FUEL A	FUEL B	FLYASH A	FLYASH B	BOTTOM ASH	WOOD FUELA	WOOD FUELB	FLYASH A	FLYASH B	BOTTOM ASH	WOOD FUELA	WOOD FUELB	FLYASH A	FLYASH B	BOTTOM ASH
<b>2,3,7,8 TCDF</b>	0.1	0.2	0.49	0.69	270	300	0.48		0.91	198	334		1.3		811	442	
<b>Other TCDF</b>	0	0.2	1.7	2.7	5250	6100	1.7	6.6	8.8	3990	6520		18.3	10	13720	8850	0.95
<b>2,3,7,8 TCDD</b>	1				25.4	29.2				18.9	30.9				81.5	61.8	
<b>Other TCDD</b>	0			0.29	1720	2050	0.22		0.77	2190	3430		2.5	0.73	8890	7500	0.34
<b>1,2,3,7,8 PeCDF</b>	0.05						0.22					0.32				165	
<b>2,3,4,7,8 PeCDF</b>	0.5		0.29		152	177	0.2	0.69	1.2	106	160				430	317	0.49
<b>Other PeCDF</b>	0		2.3	3.9	1140	1470	0.42	10	12.5	875	1290	0.32	10.8	32.7	3360	2760	1.1
<b>1,2,3,7,8 PeCDD</b>	0.5				44.4	52.2				30	58.7		0.76		156	127	0.32
<b>Other PeCDD</b>	0				1090	1290	0.24			1360	2410		0.76		6350	5590	2
<b>1,2,3,4,7,8 HxCDF</b>	0.1		1	1.2	88	103	0.19	3.8	6.3				9.8	10.6			1.3
<b>1,2,3,7,8,9-HxCDF</b>	0.1				4.6						4.9				16.2	9.2	
<b>2,3,4,6,7,8 HxCDF</b>	0.1		0.5	0.6					3.1				5.4	4.5			0.62
<b>1,2,3,6,7,8-HxCDF</b>	0.1		0.33	0.38	48.4	56.5		1	1.4	30.9	52.3		3.2		151	115	0.64
<b>Other HxCDF</b>	0	0.12	17.5	19.8	391	451	0.37	66.2	127	193	337	0.42	232	205	975	740	5.9
<b>1,2,3,4,7,8 HxCDD</b>	0.1				41.4	48.8		0.48	0.71	31.4	54.9				157	134	
<b>1,2,3,6,7,8 HxCDD</b>	0.1		2.3	1.6	45.7	53.6		6.2	10.1	41.2	64.5	0.53	18.7	22.8	191	149	0.95
<b>1,2,3,7,8,9 HxCDD</b>	0.1				81	95.1		2	2.6	63.5	91.2	0.51	4.8	6.4	277	207	1
<b>Other HxCDD</b>	0		8.6	6.2	1050	1270	1.1	35.4	51.3	1710	2490	2.8	132	122	7150	6000	8.1
<b>1,2,3,4,6,7,8 HpCDF</b>	0.01	0.17	11.5	9.4	49.4	57.9	0.24	40.6	61.8	29.9	46.2	0.87	148	174	158	103	4.2
<b>1,2,3,4,7,8,9 HpCDF</b>	0.01				8.8	10.3		3		5.3	7.3		7.7	11.7	31.8	16.6	0.43
<b>Other HpCDF</b>	0	0.56	52.2	36.9	86.5	101	0.57	182	275	52.2	80.5	2.9	684	870	292	180	13.3
<b>1,2,3,4,6,7,8 HpCDD</b>	0.01	0.48	77.2	51.8	174	208	2.3	348	464	190	306	11	967	1120	1160	801	30.6
<b>Other HpCDD</b>	0	0.72	147	106	335	395	4.2	740	1040	356	583	23.5	2320	2450	2100	1500	60.3
<b>OCDF</b>	0.001	0.79	75.1	40.8			0.59	278	353		8.1	3.4	860	1250	30.5	21.2	15.5
<b>OCDD</b>	0.001	2.9	908	585	90.8	102	15.3	4645	5265	84.4	140	86.7	10610	14455	685	432	278
<b>Reporting TEQ</b>		<b>0.030</b>	<b>2.5</b>	<b>1.7</b>	<b>183.9</b>	<b>212.4</b>	<b>0.22</b>	<b>10.5</b>	<b>14.0</b>	<b>125.7</b>	<b>204.2</b>	<b>0.33</b>	<b>27.4</b>	<b>33.2</b>	<b>549.0</b>	<b>407.3</b>	<b>1.50</b>

Table B-2. PCCD/F congeners for fuel and combustion by-products for Livermore Falls trial burn.

Compound Name	Reporting TEQ Table 405.1	BLANK	CONTROL FUEL					LOW LEVEL FUEL					MODERATE LEVEL FUEL				
			FUEL A	FUEL B	FLYASH A	FLYASH B	BOTTOM ASH	WOOD FUELA	WOOD FUELB	FLYASH A	FLYASH B	BOTTOM ASH	WOOD FUELA	WOOD FUELB	FLYASH A	FLYASH B	BOTTOM ASH
2,3,7,8 TCDF	0.1				97.2	91.5				379	419				487	487	3.9
Other TCDF	0				2000	1930				11580	10790			12.7	11530	11900	3.9
2,3,7,8 TCDD	1				20.6	19.8				84.7	94.0				89.5	84.1	
Other TCDD	0				1770	1790				5310	5020	10.0			4590	4360	
1,2,3,7,8 PeCDF	0.05	5.1							3.9	163	192				216	255	
2,3,4,7,8 PeCDF	0.5				76.2	86.9			6.8	458	534				450	514	6.7
Other PeCDF	0	5.1		6.9	613	672			153	4080	4330		35.2	30.2	4150	4540	6.7
1,2,3,7,8 PeCDD	0.5	4.0			38.3	42.5			5.0	176	224				166	200	8.9
Other PeCDD	0	4.0			1450	1480			9.4	4100	4530				4200	4850	8.9
1,2,3,4,7,8 HxCDF	0.1	3.9	4.7	3.6	65.2	75.9			10.4	329	383		23.6	27.7	327	387	5.1
1,2,3,7,8,9-HxCDF	0.1	4.3				15.0			7.7	14.6	70.9		11.2		16.4	28.3	
2,3,4,6,7,8 HxCDF	0.1	3.5	3.1						6.4	217			14.7			257	5.5
1,2,3,6,7,8-HxCDF	0.1	3.5		2.3	33.6	38.6			6.4	167	200		11.9	16.2	184	227	4.8
Other HxCDF	0	15.2	37.5	46.0	287	303		244	135	1540	1550		464	737	1470	1990	32.1
1,2,3,4,7,8 HxCDD	0.1	3.5			46.9	57.4			7.3	180	239				206	226	
1,2,3,6,7,8 HxCDD	0.1	3.1	11.3	8.5	81.3	86.9		35.4	20.8	265	323		66.0	79.3	244	271	5.8
1,2,3,7,8,9 HxCDD	0.1	4.7	8.0	4.6	91.5	106			12.0	391	471		24.7		346	383	16.4
Other HxCDD	0	11.3	45.4	34.1	1840	1900		85.0	85.3	4070	4830	4.1	258	379	4820	5110	22.2
1,2,3,4,6,7,8 HpCDF	0.01	2.9	51.4	44.5	77.0	84.6		165	126	279	344		394	387	313	382	
1,2,3,4,7,8,9 HpCDF	0.01	5.4				18.2			14.4	33.3	65.1		41.0	45.3	35.3	45.3	
Other HpCDF	0	8.3	199	185	120	118			402	361	458						1540
1,2,3,4,6,7,8 HpCDD	0.01	3.7	357	342	416	412	9.4	935	681	1140	1330	6.4	2150	2630	1240	1340	10.7
Other HpCDD	0	3.7	663	642	794	761	9.4	1650	1160	2240	2660	12.4	3730	4820	2330	2490	10.7
OCDF	0.001	8.3	266	233	57.1			917	771		118		2330	2170		89.8	
OCDD	0.001	11.8	4350	4250	452	391		10470	8370	1310	1500	31.6	26230	30950	880	1040	43.6
Reporting TEQ		5.0	11.4	10.2	124.9	137.2	0.1	25.9	30.6	619.9	712.2	0.1	69.6	76.1	606.1	699.3	12.1

Table B-3. Concentration of PCDD/F congeners of stack gas for Stratton trial burn.

Compound Name	Reporting TEQ Table 405.1	CONTROL FUEL			LOW LEVEL FUEL			MODERATE LEVEL FUEL		
		D/F-T1 (ng/dscm @7%O <sub>2</sub> )	D/F-T2 (ng/dscm @7%O <sub>2</sub> )	D/F-T3 (ng/dscm @7%O <sub>2</sub> )	D/F-T1 (ng/dscm @7%O <sub>2</sub> )	D/F-T2 (ng/dscm @7%O <sub>2</sub> )	D/F-T3 (ng/dscm @7%O <sub>2</sub> )	D/F-T1 (ng/dscm @7%O <sub>2</sub> )	D/F-T2 (ng/dscm @7%O <sub>2</sub> )	D/F-T3 (ng/dscm @7%O <sub>2</sub> )
2,3,7,8 TCDF	0.1	1.05E-02	7.12E-03	9.07E-03	7.02E-03	5.27E-03	1.95E-02	8.09E-02	2.83E-01	1.37E-01
Other TCDF	0	4.60E-01	2.63E-01	2.72E-01	2.23E-01	1.44E-01	7.41E-01	3.33E+00	1.02E+01	4.38E+00
2,3,7,8 TCDD	1	1.37E-03	1.20E-03	9.01E-04	9.49E-04	5.95E-04	1.94E-03	6.57E-03	3.49E-02	1.53E-02
Other TCDD	0	2.71E-01	2.13E-01	8.59E-02	1.11E-01	8.18E-02	1.83E-01	8.15E-01	1.06E+00	2.24E+00
1,2,3,7,8 PeCDF	0.05	5.38E-03	5.49E-03	4.14E-03	5.14E-03	2.26E-03	8.59E-03	3.68E-02	1.87E-01	7.54E-02
2,3,4,7,8 PeCDF	0.5	7.70E-03	6.65E-03	6.02E-03	5.47E-03	3.10E-03	1.17E-02	4.86E-02	2.78E-01	1.12E-01
Other PeCDF	0	9.58E-02	8.14E-02	6.84E-02	4.66E-02	2.83E-02	1.45E-01	6.43E-01	3.48E+00	1.22E+00
1,2,3,7,8 PeCDD	0.5	3.10E-03	3.23E-03	1.93E-03	2.10E-03	1.48E-03	3.27E-03	1.03E-02	5.73E-02	4.34E-02
Other PeCDD	0	1.27E-01	1.02E-01	6.03E-02	5.39E-02	4.01E-02	7.12E-02	3.28E-01	6.07E-01	1.89E+00
1,2,3,4,7,8 HxCDF	0.1	4.20E-03	5.04E-03	3.66E-03	4.86E-03	2.02E-03	4.36E-03	1.28E-02	9.77E-02	3.50E-02
1,2,3,7,8,9-HxCDF	0.1	6.63E-04	4.99E-04	4.84E-04	3.89E-04	4.50E-04	5.40E-04	3.85E-03	1.93E-02	1.13E-02
2,3,4,6,7,8 HxCDF	0.1	3.42E-03	4.55E-03	2.85E-03	3.97E-03	1.46E-03	4.12E-03	1.29E-02	9.05E-02	3.96E-02
1,2,3,6,7,8-HxCDF	0.1	3.74E-03	4.89E-03	3.51E-03	4.73E-03	1.53E-03	4.63E-03	1.36E-02	1.10E-01	4.03E-02
Other HxCDF	0	1.90E-02	2.05E-02	1.64E-02	2.45E-02	6.39E-03	2.73E-02	9.04E-02	6.56E-01	2.37E-01
1,2,3,4,7,8 HxCDD	0.1	3.45E-03	3.68E-03	2.28E-03	2.31E-03	1.61E-03	2.17E-03	7.99E-03	2.47E-02	5.32E-02
1,2,3,6,7,8 HxCDD	0.1	4.71E-03	6.28E-03	4.08E-03	3.79E-03	2.85E-03	2.90E-03	9.49E-03	2.61E-02	9.40E-02
1,2,3,7,8,9 HxCDD	0.1	3.29E-03	3.86E-03	2.61E-03	2.70E-03	1.93E-03	2.42E-03	7.04E-03	2.21E-02	6.28E-02
Other HxCDD	0	8.59E-02	6.95E-02	5.84E-02	3.98E-02	3.25E-02	4.23E-02	1.82E-01	2.72E-01	2.36E+00
1,2,3,4,6,7,8 HpCDF	0.01	1.14E-02	1.66E-02	1.08E-02	1.82E-02	6.20E-03	1.08E-02	1.63E-02	1.25E-01	4.56E-02
1,2,3,4,7,8,9 HpCDF	0.01	3.00E-03	4.23E-03	2.48E-03	4.22E-03	4.58E-04	2.66E-03	3.26E-03	1.32E-02	9.18E-03
Other HpCDF	0	6.95E-03	9.90E-03	6.80E-03	1.07E-02	1.26E-03	3.04E-03	1.01E-02	4.93E-02	2.76E-02
1,2,3,4,6,7,8 HpCDD	0.01	2.05E-02	2.78E-02	2.07E-02	1.83E-02	1.15E-02	1.32E-02	3.70E-02	6.61E-02	5.35E-01
Other HpCDD	0	1.59E-02	1.97E-02	1.53E-02	1.45E-02	8.64E-03	1.01E-02	2.77E-02	5.69E-02	3.81E-01
OCDF	0.001	2.55E-02	2.65E-02	2.20E-02	3.41E-02	1.54E-02	1.95E-02	1.57E-02	2.05E-02	1.25E-02
OCDD	0.001	3.58E-02	5.20E-02	3.39E-02	4.96E-02	4.01E-02	2.41E-02	3.24E-02	4.48E-02	4.08E-01
Reporting TEQ		1.08E-02	1.06E-02	8.33E-03	8.46E-03	4.95E-03	1.42E-02	5.33E-02	2.81E-01	1.50E-01

Table B-4. Concentration of PCDD/F congeners of stack gas for Livermore Falls trial burn.

Compound Name	Reporting TEF Table 405.1	CONTROL FUEL			LOW LEVEL FUEL			MODERATE LEVEL FUEL		
		D/F-T1 (ng/dscm @7%O <sub>2</sub> )	D/F-T2 (ng/dscm @7%O <sub>2</sub> )	D/F-T3 (ng/dscm @7%O <sub>2</sub> )	D/F-T1 (ng/dscm @7%O <sub>2</sub> )	D/F-T2 (ng/dscm @7%O <sub>2</sub> )	D/F-T3 (ng/dscm @7%O <sub>2</sub> )	D/F-T1 (ng/dscm @7%O <sub>2</sub> )	D/F-T2 (ng/dscm @7%O <sub>2</sub> )	D/F-T3 (ng/dscm @7%O <sub>2</sub> )
2,3,7,8 TCDF	0.1	1.03E-02	7.04E-03	4.78E-03	6.65E-02	5.67E-02	4.92E-02	2.59E-02	2.74E-02	3.26E-02
Other TCDF	0	2.45E-01	1.66E-01	1.35E-01	1.80E+00	1.57E+00	1.48E+00	6.39E-01	7.59E-01	9.02E-01
2,3,7,8 TCDD	1	1.85E-03	7.38E-04	7.20E-04	1.21E-02	1.02E-02	7.61E-03	4.86E-03	3.73E-03	4.44E-03
Other TCDD	0	1.35E-01	1.54E-01	1.53E-01	9.79E-01	7.26E-01	6.62E-01	6.05E-01	1.66E-01	1.89E-01
1,2,3,7,8 PeCDF	0.05	6.12E-03	2.67E-03	1.80E-03	4.68E-02	4.12E-02	3.47E-02	2.04E-02	1.97E-02	2.37E-02
2,3,4,7,8 PeCDF	0.5	8.79E-03	2.71E-03	3.53E-03	8.19E-02	7.36E-02	6.28E-02	2.86E-02	2.58E-02	3.08E-02
Other PeCDF	0	1.02E-01	6.12E-02	4.73E-02	6.83E-01	5.99E-01	5.42E-01	2.62E-01	2.53E-01	3.13E-01
1,2,3,7,8 PeCDD	0.5	4.33E-03	2.99E-03	1.87E-03	4.36E-02	3.66E-02	2.65E-02	2.21E-02	7.83E-03	1.02E-02
Other PeCDD	0	1.59E-01	1.73E-01	1.59E-01	1.23E+00	9.91E-01	7.61E-01	9.14E-01	1.91E-01	2.16E-01
1,2,3,4,7,8 HxCDF	0.1	5.36E-03	6.33E-03	2.71E-03	3.90E-02	3.51E-02	2.79E-02	1.51E-02	1.16E-02	1.43E-02
1,2,3,7,8,9-HxCDF	0.1	1.64E-03	1.52E-03	1.35E-03	1.10E-02	9.71E-03	8.21E-03	4.30E-03	3.33E-03	3.86E-03
2,3,4,6,7,8 HxCDF	0.1	7.32E-03	4.57E-03	3.26E-03	5.15E-02	4.72E-02	3.68E-02	1.94E-02	1.45E-02	1.81E-02
1,2,3,6,7,8-HxCDF	0.1	5.95E-03	3.37E-03	2.75E-03	4.18E-02	3.89E-02	2.92E-02	1.69E-02	1.32E-02	1.63E-02
Other HxCDF	0	3.57E-02	1.55E-02	1.52E-02	1.15E-01	1.01E-01	9.31E-02	4.50E-02	3.31E-02	4.84E-02
1,2,3,4,7,8 HxCDD	0.1	4.44E-03	3.96E-03	2.81E-03	3.45E-02	3.28E-02	2.45E-02	2.06E-02	6.42E-03	6.92E-03
1,2,3,6,7,8 HxCDD	0.1	1.02E-02	1.06E-02	7.83E-03	7.94E-02	6.72E-02	5.11E-02	5.85E-02	1.21E-02	1.53E-02
1,2,3,7,8,9 HxCDD	0.1	8.26E-03	7.36E-03	5.89E-03	5.47E-02	4.61E-02	3.64E-02	3.79E-02	9.43E-03	1.05E-02
Other HxCDD	0	2.78E-01	2.84E-01	2.83E-01	8.90E-01	7.38E-01	5.77E-01	6.12E-01	1.48E-01	1.55E-01
1,2,3,4,6,7,8 HpCDF	0.01	1.49E-02	9.20E-03	7.21E-03	1.03E-01	9.03E-02	6.85E-02	4.26E-02	2.54E-02	3.21E-02
1,2,3,4,7,8,9 HpCDF	0.01	1.33E-03	1.08E-03		9.41E-03	8.84E-03	6.70E-03	3.87E-03	3.20E-03	3.12E-03
Other HpCDF	0	6.86E-03	3.63E-03	5.55E-04						
1,2,3,4,6,7,8 HpCDD	0.01	8.20E-02	7.29E-02	6.29E-02	4.29E-01	3.46E-01	2.46E-01	2.07E-01	5.73E-02	5.95E-02
Other HpCDD	0	6.84E-02	6.22E-02	5.37E-02						
OCDF	0.001	7.30E-03	4.49E-03	3.86E-03	3.14E-02	2.64E-02	2.03E-02	1.38E-02	6.92E-03	8.01E-03
OCDD	0.001	1.36E-01	1.11E-01	9.87E-02	9.44E-01	6.84E-01	4.69E-01	2.29E-01	9.61E-02	8.30E-02
Reporting TEQ		1.52E-02	9.14E-03	7.45E-03	1.21E-01	1.06E-01	8.40E-02	5.39E-02	3.23E-02	3.90E-02

Table B-5. Emission rate of PCDD/F congeners for Stratton trial burn.

Compound Name	Reporting TEF Table 405.1	Average (kg/hr)		
		Control	Low	Moderate
2,3,7,8 TCDF	0.1	4.33E-09	5.38E-09	7.03E-08
Other TCDF	0	1.63E-07	1.88E-07	2.52E-06
2,3,7,8 TCDD	1	5.70E-10	5.91E-10	7.76E-09
Other TCDD	0	9.47E-08	6.40E-08	6.63E-07
1,2,3,7,8 PeCDF	0.05	2.46E-09	2.72E-09	4.07E-08
2,3,4,7,8 PeCDF	0.5	3.33E-09	3.44E-09	5.94E-08
Other PeCDF	0	4.02E-08	3.73E-08	7.18E-07
1,2,3,7,8 PeCDD	0.5	1.36E-09	1.16E-09	1.58E-08
Other PeCDD	0	4.77E-08	2.81E-08	4.60E-07
1,2,3,4,7,8 HxCDF	0.1	2.11E-09	1.92E-09	1.93E-08
1,2,3,7,8,9-HxCDF	0.1	2.69E-10	2.35E-10	4.82E-09
2,3,4,6,7,8 HxCDF	0.1	1.78E-09	1.63E-09	1.93E-08
1,2,3,6,7,8-HxCDF	0.1	1.99E-09	1.85E-09	2.17E-08
Other HxCDF	0	9.15E-09	9.89E-09	1.31E-07
1,2,3,4,7,8 HxCDD	0.1	1.55E-09	1.04E-09	1.35E-08
1,2,3,6,7,8 HxCDD	0.1	2.47E-09	1.63E-09	2.11E-08
1,2,3,7,8,9 HxCDD	0.1	1.60E-09	1.20E-09	1.48E-08
Other HxCDD	0	3.50E-08	1.95E-08	4.78E-07
1,2,3,4,6,7,8 HpCDF	0.01	6.38E-09	6.00E-09	2.49E-08
1,2,3,4,7,8,9 HpCDF	0.01	1.60E-09	1.25E-09	3.67E-09
Other HpCDF	0	3.88E-09	2.57E-09	1.22E-08
1,2,3,4,6,7,8 HpCDD	0.01	1.13E-08	7.35E-09	1.08E-07
Other HpCDD	0	8.32E-09	5.68E-09	7.82E-08
OCDF	0.001	1.21E-08	1.18E-08	7.39E-09
OCDD	0.001	2.00E-08	1.95E-08	8.26E-08
Reporting TEQ		4.87E-09	4.69E-09	6.73E-08



Table B-6. Emission rate of PCDD/F congeners for Livermore Falls trial burn.

Compound Name	Reporting TEF Table 405.1	Average (kg/hr)		
		Control	Low	Moderate
2,3,7,8 TCDF	0.1	1.63E-09	1.35E-08	6.76E-09
Other TCDF	0	4.02E-08	3.80E-07	1.81E-07
2,3,7,8 TCDD	1	2.44E-10	2.34E-09	1.03E-09
Other TCDD	0	3.29E-08	1.86E-07	7.39E-08
1,2,3,7,8 PeCDF	0.05	7.76E-10	9.62E-09	5.03E-09
2,3,4,7,8 PeCDF	0.5	1.11E-09	1.71E-08	6.71E-09
Other PeCDF	0	1.55E-08	1.43E-07	6.53E-08
1,2,3,7,8 PeCDD	0.5	6.76E-10	8.35E-09	3.12E-09
Other PeCDD	0	3.64E-08	2.34E-07	1.02E-07
1,2,3,4,7,8 HxCDF	0.1	1.05E-09	7.98E-09	3.22E-09
1,2,3,7,8,9-HxCDF	0.1	3.33E-10	2.26E-09	9.03E-10
2,3,4,6,7,8 HxCDF	0.1	1.12E-09	1.06E-08	4.09E-09
1,2,3,6,7,8-HxCDF	0.1	8.89E-10	8.62E-09	3.65E-09
Other HxCDF	0	4.90E-09	2.41E-08	9.93E-09
1,2,3,4,7,8 HxCDD	0.1	8.26E-10	7.17E-09	2.62E-09
1,2,3,6,7,8 HxCDD	0.1	2.11E-09	1.55E-08	6.62E-09
1,2,3,7,8,9 HxCDD	0.1	1.59E-09	1.08E-08	4.46E-09
Other HxCDD	0	6.26E-08	1.73E-07	7.08E-08
1,2,3,4,6,7,8 HpCDF	0.01	2.30E-09	2.05E-08	7.85E-09
1,2,3,4,7,8,9 HpCDF	0.01	1.74E-10	1.95E-09	7.98E-10
Other HpCDF	0	8.03E-10		
1,2,3,4,6,7,8 HpCDD	0.01	1.61E-08	7.98E-08	2.50E-08
Other HpCDD	0	1.36E-08		
OCDF	0.001	1.16E-09	6.12E-09	2.24E-09
OCDD	0.001	2.55E-08	1.64E-07	3.17E-08
Reporting TEQ		2.34E-09	2.44E-08	9.80E-09



**APPENDIX C -  
SAMPLE CALCULATION OF INPUT  
AND OUTPUT RATES**

### Example calculation for arsenic input and output rates for Stratton Control Run

(computed results presented below differ slightly from that given in report due to rounding)

#### Fuel input

Fuel input rate based on total weight = 53.4 ton/hr (from Table 9)

Percent solids of fuel = 45.4% (from Table 9)

Fuel input rate based on solids weight =  $53.4 \text{ ton/hr} \times 45.4\% = 24.2 \text{ ton/hr} \times 907.2 \text{ kg/ton}$   
 $= 21,994 \text{ kg/hr}$  (reported in Table 9)

As concentration in fuel = 1.8 mg/kg (from Table 7)

As input rate in fuel =  $1.8 \text{ mg/kg} \times 21,994 \text{ kg/hr} = 39,589 \text{ mg/hr} \times 1 \text{ mg/1,000,000 kg}$   
 $= 0.040 \text{ kg/hr}$  (reported in Table 11)

#### Fly ash output

Fly ash output rate based on total weight = 1.7 ton/hr (from Table 9)

Percent solids of fly ash = 69.0% (from Table 9)

Fly ash output rate based on solids weight =  $1.7 \text{ ton/hr} \times 69.0\% =$   
 $1.17 \text{ ton/hr} \times 907.2 \text{ kg/ton} = 1064 \text{ kg/hr}$  (reported in Table 9)

As concentration in fly ash = 84.5 mg/kg (from Table 7)

As output rate in fly ash =  $84.5 \text{ mg/kg} \times 1064 \text{ kg/hr} = 89,930 \text{ mg/hr} \times 1 \text{ mg/1,000,000 kg}$   
 $= 0.090 \text{ kg/hr}$  (reported in Table 11)

#### Bottom ash output

Bottom ash output rate based on total weight = 1.7 ton/hr (from Table 9)

Percent solids of bottom ash = 83.0% (from Table 9)

Bottom ash output rate based on solids weight =  $1.7 \text{ ton/hr} \times 83.0\% =$   
 $1.41 \text{ ton/hr} \times 907.2 \text{ kg/ton} = 1280 \text{ kg/hr}$  (reported in Table 9)

As concentration in bottom ash = 25 mg/kg (from Table 7)

As output rate in bottom ash =  $25 \text{ mg/kg} \times 1280 \text{ kg/hr} = 32,000 \text{ mg/hr}$   
 $\times 1 \text{ mg/1,000,000 kg} = 0.032 \text{ kg/hr}$  (reported in Table 11)

#### Stack gas output

Stack gas output as given by Airtox =  $1.587 \times 10^{-4} \text{ kg/hr}$  (from Table 11)

#### Output sum

$0.090 \text{ kg/hr} + 0.032 \text{ kg/hr} + 1.587 \times 10^{-4} \text{ kg/hr} = 0.122 \text{ kg/hr}$  (reported in Table 11)

#### % Diff

Percent difference of output versus input =  $(0.122 \text{ kg/hr} - 0.040 \text{ kg/hr}) / 0.040 \text{ kg/hr} \times 100$   
 $= 205\%$  (reported in Table 11)

**APPENDIX D -  
RESULTS OF THE BORALEX STRATTON AND BORALEX  
LIVERMORE FALLS AMBIENT AIR QUALITY IMPACT  
MODELING ANALYSIS FOR THE TRIAL COMBUSTION BURN  
OF CONSTRUCTION AND DEMOLITION WOOD DEBRIS OF 2003  
AND 2004**

## MEMORANDUM

**DATE:** March 17, 2005

**TO:** Dana N. Humphrey, Ph.D., P.E. University of Maine  
Consultant to Boralex Regarding Trial Combustion Burns of Construction  
and Demolition Wood Debris, 2003 and 2004

**FROM:** Kevin J. Ostrowski, Senior Meteorologist,  
Mark Eric Roberts P.E., Project Engineer,  
Marc Allen Robert Cone, P.E., Project Engineer,  
Maine Department of Environmental Protection  
Bureau of Air Quality (MEDEP-BAQ)

**RE:** Results of the Boralex Stratton and Boralex Livermore Falls Ambient Air  
Quality Impact Modeling Analysis for the Trial Combustion Burn of  
Construction and Demolition Wood Debris of 2003 and 2004

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### **Ambient Air Quality Impact Analysis**

#### **A. Overview**

A refined ambient air quality impact dispersion modeling analysis was recently performed to determine the ambient air quality impacts for arsenic and dioxins associated with the test burning of construction demolition wood debris (CDD) at the Boralex-Stratton and Boralex-Livermore Falls facilities. This modeling was recently performed by MEDEP-BAQ.

#### **B. Model Inputs**

The Industrial Source Complex Short Term 3 (ISCST3) model was used in refined mode to evaluate predicted impacts in simple, intermediate and complex terrain (i.e., involves areas where terrain elevations are below stack-top height, to above stack-top elevations).

A network of receptor grids was constructed for each facility, based upon North American Datum (NAD83) elevation data. The receptor grids were nested with the following spacing: 100 meter, 500 meter and 1000 meter intervals.

All modeling was performed in accordance with all applicable requirements of the MEDEP-BAQ and the United States Environmental Protection Agency (USEPA).

Valid meteorological databases were used in the ISCST3 refined modeling analyses as follows:

### **Boralex Stratton**

A 5-year hourly off-site meteorological database was used in the refined modeling. Wind data was collected at a height of 10.00 meters at the S.D. Warren (Hinckley) meteorological monitoring site during the 5-year period 1991-1994; 1996. Each year of meteorological data met the 90% data recovery requirement, both singularly and jointly. Missing data were interpolated or coded as missing, per EPA guidance. Stability was calculated by using sigma-phi data (the standard deviation of the elevation angle of the wind), based upon four 15-minute averages, and wind data measured at the 10-meter level at the S.D. Warren meteorological monitoring site. Hourly mixing heights were derived from Caribou National Weather Site (NWS) surface and upper air data.

### **Boralex Livermore Falls**

A 5-year hourly off-site meteorological database was used in the ISCST3 refined modeling analysis. Wind data was collected at a height of 15.00 meters at the Augusta Airport MEDEP meteorological monitoring site during the 5-year period 1984-1988. Each year of meteorological data met the 90% data recovery requirement, both singularly and jointly. Missing data were interpolated or coded as missing, per EPA guidance. Hourly cloud cover, ceiling height and wind data measured at the 15-meter level, also collected at the Augusta Airport MEDEP site, was used to determine stability. Hourly mixing heights were derived from Portland NWS surface and upper air data.

Point-source parameters, used in the modeling for both Boralex facilities are listed in Table D-1. Since both stacks were calculated to be above full Good Engineering Practice (GEP) height, building wake effects on emissions from modeled stacks were not taken into account.

Table D-1. Point source stack parameters.

Facility/Stack	Stack Base Elevation (m)	Stack Height (m)	Stack Diameter (m)	UTM Easting NAD83 (km)	UTM Northing NAD83 (km)
<b>Boralex Stratton</b>					
Main Stack	353.56	88.39	2.79	387.863	4999.551
<b>Boralex Livermore</b>					
Main Stack	121.92	67.10	2.44	407.475	4920.525

Emission parameters for both Boralex facilities are listed in Table D-2. The emission parameters are based on the results from the recent CDD trial burns.

Table D-2. Stack emission parameters.

Facility/Stack	Averaging Periods	Arsenic Emission Rate (g/s)	Dioxin Emission Rate (g/s)	Stack Temp (K)	Stack Velocity (m/s)
<b>Boralex Stratton</b>					
Main Stack	All	1.87E-03	1.87E-08	450.00	19.83
<b>Boralex Livermore</b>					
Main Stack	All	7.95E-03	6.78E-09	450.00	21.95

### C. Ambient Air Quality Modeled Impacts

ISCST3 refined modeling, using 5 years of off-site meteorological data, was performed using the point source and emission parameters previously listed.

The model results for Boralex Livermore Falls and Boralex Stratton are shown in Tables D-3a and D-4a, respectively. Maximum predicted ambient air quality impacts did not exceed their respective Maine Ambient Air Guideline values (MAAG) as indicated in boldface type. Tables D-3b and D-4b compare the model results to the MAAG values and presents the results as a percent of the MAAG.

Table D-3a. Maximum ISCST3 impacts from Boralex Livermore Falls.

Pollutant	Averaging Period	Max Impact ( $\mu\text{g}/\text{m}^3$ )	Receptor UTM E (km)	Receptor UTM N (km)	Receptor Elevation (m)	Met Data Year	MAAG ( $\mu\text{g}/\text{m}^3$ )
Arsenic	Annual	<b>4.20E-04</b>	409450	4919750	198.12	1984	<b>2.00E-03</b>
	Annual	<b>5.20E-04</b>	409450	4919750	198.12	1985	<b>2.00E-03</b>
	Annual	<b>4.80E-04</b>	409450	4919750	198.12	1986	<b>2.00E-03</b>
	Annual	<b>4.70E-04</b>	409450	4919750	198.12	1987	<b>2.00E-03</b>
	Annual	<b>6.00E-04</b>	409450	4919750	198.12	1988	<b>2.00E-03</b>
Dioxin	Annual	<b>9.95E-10</b>	409450	4919750	198.12	1984	<b>3.00E-07</b>
	Annual	<b>1.22E-09</b>	409450	4919750	198.12	1985	<b>3.00E-07</b>
	Annual	<b>1.14E-09</b>	409450	4919750	198.12	1986	<b>3.00E-07</b>
	Annual	<b>1.10E-09</b>	409450	4919750	198.12	1987	<b>3.00E-07</b>
	Annual	<b>1.42E-09</b>	409450	4919750	198.12	1988	<b>3.00E-07</b>



Table D-3b. Max impact as a percent of MAAG value for Boralex Livermore Falls.

<b>Pollutant</b>	<b>Averaging Period</b>	<b>Max Impact (µg/m³)</b>	<b>MAAG (µg/m³)</b>	<b>Max Impact as a Percent of MAAG (Max Impact/MAAG X 100)</b>
Arsenic	Annual	4.20E-04	2.00E-03	21
	Annual	5.20E-04	2.00E-03	26
	Annual	4.80E-04	2.00E-03	24
	Annual	4.70E-04	2.00E-03	24
	Annual	6.00E-04	2.00E-03	30
Average Max Impact as a Percent of MAAG				<b>25</b>
Dioxin	Annual	9.95E-10	3.00E-07	0.33
	Annual	1.22E-09	3.00E-07	0.41
	Annual	1.14E-09	3.00E-07	0.38
	Annual	1.10E-09	3.00E-07	0.37
	Annual	1.42E-09	3.00E-07	0.47
Average Max Impact as a Percent of MAAG				<b>0.39</b>

Table D-4a. Maximum ISCST3 impacts from Boralex Stratton.

<b>Pollutant</b>	<b>Averaging Period</b>	<b>Max Impact (µg/m³)</b>	<b>Receptor UTM E (km)</b>	<b>Receptor UTM N (km)</b>	<b>Receptor Elevation (m)</b>	<b>Met Data Year</b>	<b>MAAGV (µg/m³)</b>
Arsenic	Annual	<b>7.00E-05</b>	389600	5001800	463.30	1984	<b>2.00E-03</b>
	Annual	<b>5.00E-05</b>	389100	4996300	475.49	1991	<b>2.00E-03</b>
	Annual	<b>6.00E-05</b>	389800	4999100	597.41	1992	<b>2.00E-03</b>
	Annual	<b>7.00E-05</b>	388900	4998600	445.01	1993	<b>2.00E-03</b>
	Annual	<b>7.00E-05</b>	388700	4998700	463.30	1994	<b>2.00E-03</b>
Dioxin	Annual	<b>7.25E-10</b>	389600	5001800	463.30	1991	<b>3.00E-07</b>
	Annual	<b>5.46E-10</b>	389100	4996300	475.49	1992	<b>3.00E-07</b>
	Annual	<b>6.10E-10</b>	389800	4999100	597.41	1993	<b>3.00E-07</b>
	Annual	<b>7.24E-10</b>	388900	4998600	445.01	1994	<b>3.00E-07</b>
	Annual	<b>6.53E-10</b>	388700	4998700	463.30	1996	<b>3.00E-07</b>

Table D-4b. Max impact as a percent of MAAG for Boralex Stratton.

<b>Pollutant</b>	<b>Averaging Period</b>	<b>Max Impact (<math>\mu\text{g}/\text{m}^3</math>)</b>	<b>MAAG (<math>\mu\text{g}/\text{m}^3</math>)</b>	<b>Max Impact as a Percent of MAAG (Max Impact/MAAG X 100)</b>
Arsenic	Annual	7.00E-05	2.00E-03	3.5
	Annual	5.00E-05	2.00E-03	2.5
	Annual	6.00E-05	2.00E-03	3.0
	Annual	7.00E-05	2.00E-03	3.5
	Annual	7.00E-05	2.00E-03	3.5
Average Max Impact as a Percent of MAAG				<b>3.2</b>
Dioxin	Annual	7.25E-10	3.00E-07	0.24
	Annual	5.46E-10	3.00E-07	0.18
	Annual	6.10E-10	3.00E-07	0.20
	Annual	7.24E-10	3.00E-07	0.24
	Annual	6.53E-10	3.00E-07	0.22
Average Max Impact as a Percent of MAAG				<b>0.22</b>

#### Discussion of Results:

The MAAG values for arsenic and dioxins were developed by the Department of Human Services', Bureau of Health's, Environmental Health Unit (EHU). The EHU uses a risk-based approach for developing MAAG values that are set to be protective for both carcinogenic effects and noncarcinogenic effects. When considering non carcinogenic toxicological effects, the levels are set that represent a minimal risk of a deleterious effect from lifetime exposure even for sensitive subpopulations. For carcinogenic or probable human carcinogens the MAAG values are derived using a quantitative estimate for the chemical's inhalation carcinogenic potency which is used with the target incremental lifetime cancer risk over background rates of a cancer risk of one in one-hundred thousand to calculate the MAAG value. Thus, a lifetime exposure above the Maine Ambient Air Guideline concentration value could result in a cancer occurrence of one in on hundred thousand individuals.

#### Conclusions:

The worst case ambient air quality impact results from the Livermore Falls facility were only 30% of the MAAG value for arsenic and 0.47% of the MAAG value for dioxin. In the case of the Stratton facility, the worst case impact levels were 3.5% of the MAAG value for arsenic and 0.24% of the MAAG value for dioxin. Thus, the Department concludes that the levels of dioxin and arsenic that would be emitted from the burning of CDD material at these levels would not have significant public health impact from an ambient air quality standpoint.

**APPENDIX E -  
CDW SAMPLE PREPARATION AND  
PHYSICAL ANALYSIS PROCEDURES**

<b>CDW Sample Preparation Procedure</b>	Boralex November 2002 Revision 1.1 Page 1
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## **1.0 PURPOSE**

This procedure describes how to perform the preparation of construction & demolition wood (CDW) samples for Boralex Stratton Energy, Inc., Boralex Athens Energy, Inc. and Boralex Livermore Falls, Inc. (Boralex). The information provided by this procedure will be used to determine if the subject CDW chip source is an acceptable fuel for Boralex's Maine wood-burning electrical generation facilities.

## **2.0 PROCEDURE**

### **2.1 SAMPLE PREPARATION**

Mix the composite sample to a homogeneous state using the aggregate "quartering" method developed by the American Society for Testing and Materials (ASTM) (ASTM C702, "Standard Methods for Reducing Field Samples of Aggregate to Testing Size", Method B – Quartering) as follows:

- Mix the 15-gallon sample with shovels on a smooth, clean surface with an area large enough to handle the initial sample size (approximately 8' by 8'), indoors at room temperature.
- Shape the sample into a conical pile and quarter.
- Collect two opposing quarters (approximately 7.5-gallons) and submit for chemical analysis.
- Combine the two remaining quarters and repeat the mixing and quartering.
- Collect two opposing quarters (approximately 4-gallons) and air-dry the sample for a minimum of 24 hours. Submit the sample for physical analysis.
- Retain the remaining quarters for additional analysis, if necessary.

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**1.0 PURPOSE**

This procedure describes how to perform the physical analysis of construction & demolition wood (CDW) samples for Boralex Stratton Energy, Inc., Boralex Athens Energy, Inc. and Boralex Livermore Falls, Inc. (Boralex). The information provided by this procedure will be used to determine if the subject CDW chip source is an acceptable fuel for Boralex's Maine wood-burning electrical generation facilities.

**2.0 PROCEDURE****2.1 PHYSICAL ANALYSIS**

Perform the following analyses in sequential order on the CDW sample (approximately 4-gallons).

**2.1.1 Moisture Equilibrium**

The moisture content of the sample should be approximately at equilibrium with the testing environment to prevent weight changes due to drying during analysis.

Spread the sample in the testing environment on a flat surface to approximately 3 inches in thickness. Let sample sit for a minimum of 24 hours to equilibrate.

**2.1.2 Gradation**

After weighing and recording the weight of the sample, run the entire sample through a 3-inch sieve. Collect materials that are over 3 inches in size and determine the percent by weight of the sample. Run the materials that are less than 3 inches in size through a #4 sieve (with intermediate sieves as required), which retains material greater than approximately one-quarter inch in size. Collect the fine materials that pass through the #4 sieve and determine the percent by weight of the sample. Save the fine materials for the non-burnable content determination step. Save the materials that did not pass through the #4 sieve for the physical separation step. Report results as a percent by weight of the total sample for the following components:

- 3-inch plus
- fines (#4 minus)

**2.1.3 Physical Separation**

Take the material that passed through the 3-inch sieve but did not pass the #4 sieve and separate manually into the following components

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- plastics (including carpet, PVC and plastic coated wire)
- treated wood
- painted wood
- non-combustible materials (metals, rocks, etc.)
- combustible materials

Weigh each component and determine the percent by weight of the total sample for each.

#### 2.1.4 Non-Burnable Content Determination

Determine the ash weight of the fine materials by burning-off the organic component of the fines in a high temperature "muffle" furnace and weighing the resultant ash. Combine the weight of the ash with the weight of the non-burnable materials collected through visual examination and divide by the total sample weight. This is the percent by weight of non-burnable materials in the sample.

## 2.2 REPORT

Complete a letter report, clearly identifying the sample that was analyzed, describing the analytical procedures used and provide the following data results as the percent of total sample by weight:

- 3-inch plus
- fines (#4 minus)
- plastics (including carpet, PVC and plastic coated wire)
- treated wood
- painted wood
- non-combustible materials (metals, rocks, etc.)
- combustible materials
- non-burnable content (ash fines and non-combustible materials)